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POLICY REPORT

City of Industry

Seismic Safety & Public
Safety Elements

1975

March 1975

envicom corporation

PHYSICAL, ECOLOGICAL and SOCIAL SCIENCE CONSULTANTS

May 12, 1975

City of Industry
c/o National Engineering Co.
255 N. Hacienda Blvd.
Suite 222
Industry, California

ATTN: Mr. Mike Booth

RE: City of Industry Seismic Safety and Public Safety General Plan Elements

Dear Mr. Booth:

Forwarded herewith is the Seismic Safety and Public Safety Element report for the City of Industry. The report has been prepared with the intent to meet and comply with current California State Guidelines governing preparation of these General Plan Elements.

We commend the City for participating in the ambitious and innovative program which has resulted in the largest cooperative multi-government General Plan study in the State. Special acknowledgement is extended to you and Mr. George O. Asch for participation and written contributions to this report.

Our appreciation is extended for the opportunity to prepare this challenging technical study.

Respectfully submitted,

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I. INTRODUCTION

A. Authority

The California State Legislature, through requirements of the Safety and Seismic Safety Elements, has placed specific responsibilities on local government for identification and evaluation of natural hazards and the formation of programs and regulations to reduce risk. Specific authority is derived from Government Code Sections 65302(f) and 65302.1 which requires Safety and Seismic Safety Elements of all city and county general plans, as follows:

> "A Safety Element for the protection of the community from fires and geologic hazards including features necessary for such protection as evacuation routes, peak load water supply requirements, minimum road widths, clearances around structures, and geologic hazard mapping in areas of known geologic hazards.
>
> A Seismic Safety Element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.
>
> The Seismic Safety Element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure, and seismically induced waves."

The effect of these sections is to require cities and counties to take natural hazards into account in their planning programs. The basic objective is to reduce loss of life, injuries, damage to property, and economic and social dislocations resulting from such disasters.

The catalyst for this action stemmed largely from the February 9, 1971 earthquake in which 65 people were killed and property damage exceeded the billion dollar mark. Recent conclusions from the Urban Geology Master Plan prepared by the California Division of Mines and Geology have also added impetus. Summary conclusions from this study estimate dollar losses due to geologic hazards over the next 26 years to total $55 billion (Figure 1).

B. Purpose

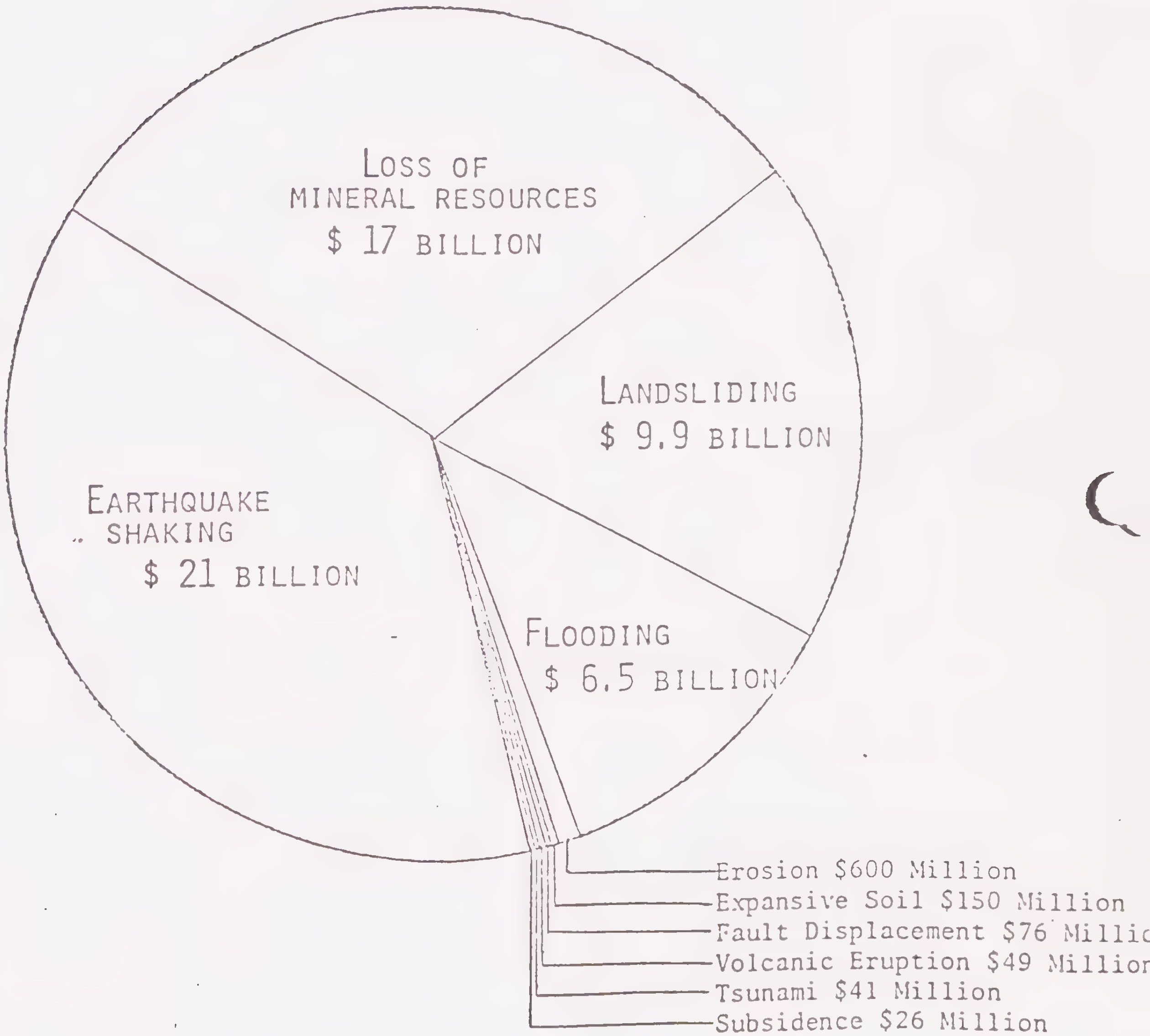
1. To fulfill the requirement of State Planning Law (Sections 65302(f) and 65302.1 Government Code), which states that Safety

FIGURE 1.

GEOLOGIC HAZARDS IN CALIFORNIA

TO THE YEAR 2000:

A $55 BILLION PROBLEM



Source: Urban Geology, Master Plan for California, Bulletin 198

and Seismic Safety Elements are mandated parts of the General Plan required by each city and county in the State of California.

2. To identify, appraise, and reduce mitigable seismic, geologic, fire, and inundation hazards to an acceptable level of risk with the overall objective of reducing loss of life, injuries, damage to property, and social-economic dislocations resulting from such natural occurrences.

3. To assist in allocation of public resources in the City of Industry and to develop information regarding safety and seismic hazards and thereby to develop a systematic approach to the protection of public health, safety and welfare from such hazards. Such information and protective devices are designed for further judicious growth and land use policies in conjunction with previously established City policies contained within the General Plan.

The Safety and Seismic Safety Element shall serve as a policy document for use by Planning, Building, and Public Services Departments, other concerned governmental and private agencies, and individual citizens, in determining the nature and extent of geologic and other hazards in the City of Industry. For the City Council and Planning Commission, the Safety and Seismic Safety Element provides a reference to be used in connection with their decisions on private development, capital improvement programs, and other implementation matters within their jurisdiction.

The Policy statements and Implementation programs contained herein, provide direction and a course of future action for reducing natural and man-made hazards. Thus, the seismic, geologic, fire, and inundation considerations will be included in determining future land use.

C. Approach

This element has been divided into two component report sections. The first, the Policy Report, defines the City policy and implementation program to respond to safety hazards delineated in the second, the Technical Report, which addresses the technical research, analyses, and findings that are the basis of the decision making process. The intent is for the Safety and Seismic Safety Element to be a planning tool for use by the City government in implementing a program to reduce safety hazards. The basic organizational structure and methodology for this study is illustrated in Figure 2.

The philosophy of this report is that the Safety and Seismic Safety Elements shall plan for the future based upon what we know today, rather than waiting until we know all that we would like to know.

METHODOLOGY FOR TECHNICAL AND POLICY REPORT PREPARATION

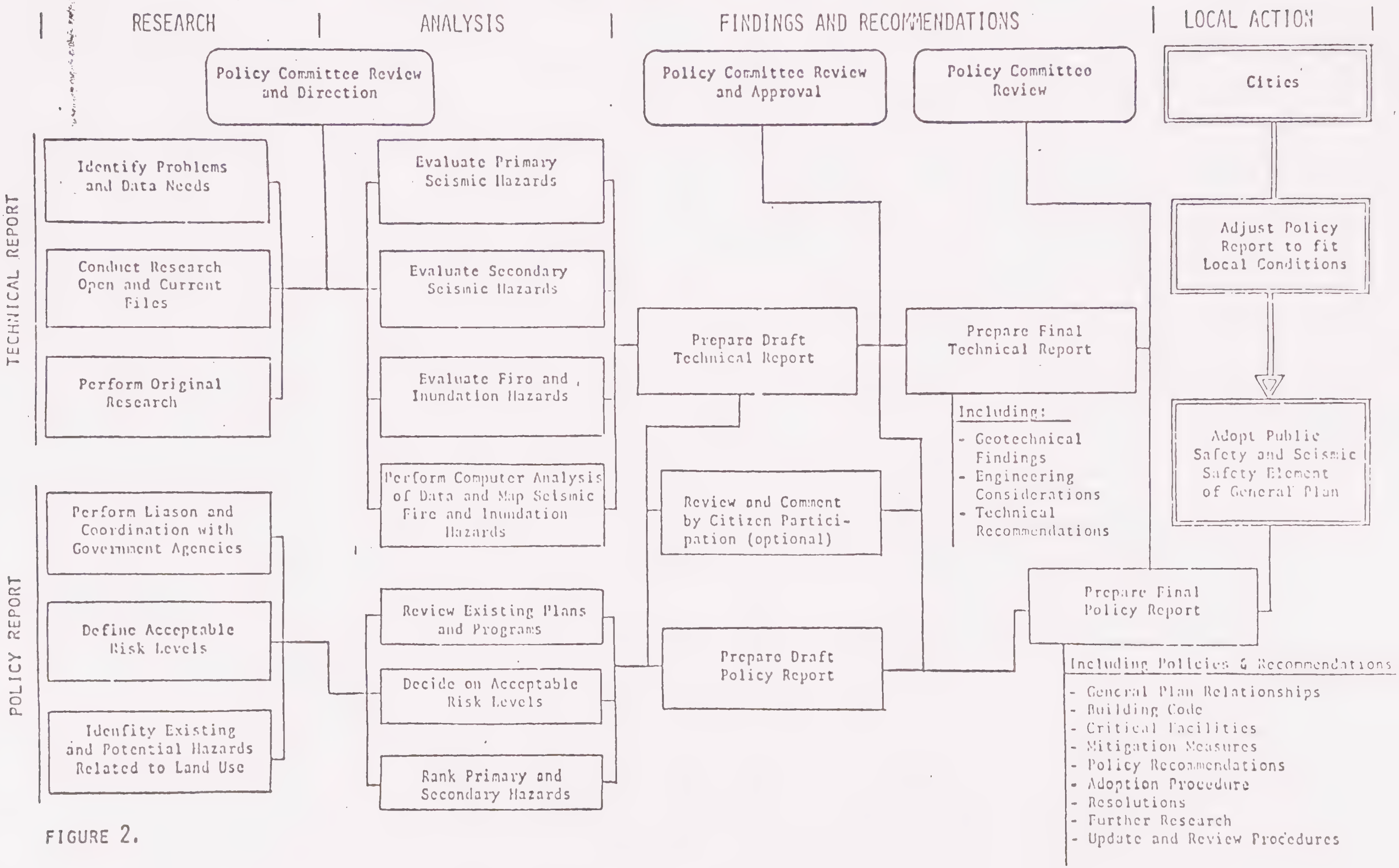


FIGURE 2.

D. METHODOLOGY

1. Distribution of Responsibility

The methodology employed during this study places emphasis on those particular hazards that can best be defined on an area-wide basis. Natural hazards that must be evaluated as a part of individual site investigations are treated less specifically so that the results may be used to facilitate the administration of public safety. The relationship and attendant responsibilities between this concept and the evaluation of specific hazards is detailed in the table on the following page.

The primary responsibility for evaluation of each aspect of a hazard is shown by an "XX" with a "XXX" used if a determination of acceptable risk is also involved. Those aspects for which either sector may commonly have a secondary responsibility are indicated by an "X." The intent is to show the distribution of responsibility for evaluation of a hazard; the overall regulatory responsibility of government is not included.

2. Types of Hazards

The several seismic hazards discussed in the C.I.R. Guidelines can be grouped as either a cause or an effect, which is the basis for the order of their consideration. Earthquakes orginate as the shock wave generated by movement along an active fault. The primary natural hazards are ground shaking and the potential for ground rupture along the surface trace of the fault. Secondary natural hazards result from the interaction of ground shaking with existing ground instabilities, and include liquefaction, settlement, and landslides. In this context, tsunamis, or "tidal waves," and seiches (often considered secondary hazards) would be primary natural hazards.

The potentially damaging natural events (hazards) discussed above may interact with man-made structures. If the structure is unable to accommodate the natural event, failure will occur. The potential for damage or injury that could occur as the result of movement of loose or inadequately restrained objects within, on, or adjacent to a structure.

The products developed in the study, as documented in the Technical Report, are primarily displayed on Plates I and II. They include hazard management, seismic, slope instability, fire and inundation zones, and secondary hazard areas.

3. Seismic Ground Shaking Zones

The derivation of the seismic zones have been documented in the Technical Report. The methodology analyzes the variation in earthquake shaking resulting from variation in earth properties.

DISTRIBUTION OF RESPONSIBILITY FOR EVALUATION OF NATURAL HAZARDS

Hazard	Responsible Sector: Public	Responsible Sector: Private
1. Fault Rupture:		
a. Evaluation of fault	XXX	
b. Location at site		XX
2. Earthquake shaking:		
a. Sources of shaking	XXX	
b. General levels of shaking	XX	X
c. Effects on site		XX
3. Fire Hazard:		
a. Risk of occurrence	XX	
b. Effects on site		XX
4. Flooding:		
a. Risk of occurrence	XXX	
b. Regional evaluation	XX	X
c. Effects on site.		XX
5. Dam failure:		
a. Risk of occurrence	XXX	
b. Effects on site		XX
6. Landslide:		
a. Regional evaluation	XXX	
b. Effects on site		XX
7. Liquefaction, settlement, and subsidence:		
a. Regional evaluation	XX(1)	
b. Effects on site		XX

X = Secondary responsibility
XX = Primary responsibility
XXX = Primary responsibility with determination of acceptable risk necessary.

(1) Evaluation requires determination of expected shaking.

II. RISK ANALYSIS

The Council on Intergovernmental Relations (CIR) Guidelines separates risk into three distinct categories:

1. Acceptable Risk - level of risk below which no specific action by government is deemed to be necessary.

2. Unacceptable Risk - the level of risk above which specific action by government is deemed to be necessary to protect life and property.

3. Avoidable Risk - risk not necessary to take because individual or public goals can be achieved at the same, or less, total "cost" by other means without taking the risk.

The level of risk must be determined. In making this determination, the appropriate planning response to a potential hazard involves a judgment, either expressed or implicit, of the risk that is acceptable. There is no such thing as a perfectly hazard-free environment. Natural and man-made hazards of some kind and degree are always present. However, efforts can be undertaken to mitigate the consequences of <u>known</u> hazards.

In the context of the Safety and Seismic Safety Elements, the evaluation of risk determines public policy and the appropriate allocation of public resources to mitigate hazards. The Element provides a framework in which response to the questions of risk can be meaningful. The first step is the recognition of the presence of a hazard.

Once a hazard has been identified, considerable effort is required to evaluate its likely severity, frequency, and the characteristics of the area involved. For a specific solution proposal this evaluation takes into account the benefit/cost ratio of reducing the hazard and acknowledges the intangibles involved. A comparison of this evaluation to that of other projects should determine priorities. The factors of voluntary and involuntary exposure to risk must considered in making this determination.

Since it is the public that both receives and eventually pays for the protection, the choice of the level at which risk becomes "acceptable" is a matter of public involvement with the determination being made by their elected representatives.

The following discussion is intended to quantify risk and to present recommendations regarding acceptable risk where appropriate. Such recommendations are based upon technical findings as presented in the Technical Report.

A. Fire Hazard

The risk of wide-spread fire in the heavily populated valley floor is low to negligible. The hillside areas to the north and south comprise three additional risk categories - "medium", "high", and "extreme", based upon four determinants (1) human proximity, (2) vegetative cover, (3) slope, and (4) access. Not all possible combinations are shown under each risk category, for stacking tends to occur among risk determinants. The risk areas are shown on Plate II, and a summary of what factors constitute each category is presented below:

Extreme Risk

Vegetation:	chamise chaparral
Proximity:	fronting developed areas and/or west of fire prone communities
Access:	limited, topography extremely variable
Slope:	steep (40%+)

High Risk

Vegetation:	Woodland-grass
Proximity:	ranging from areas fronting developments to backcountry
Access:	somewhat limited
Slope:	moderate (20-40%)

Medium Risk

Vegetation:	grassland, lesser-developed sage scrub
Proximity:	vicinity of developed areas west of fire sources
Access:	available
Slope:	level to gentle (0-20%)

Low Risk

Vegetation:	cultivated/urban - barren areas
Proximity:	developed areas
Access:	available
Slope:	flat

B. Inundation

Decisions concerning acceptable risk relative to flood inundation are required only in those areas subject to inundation within the first sixty (60) minutes following a dam failure (see Plate II). The principal reason for this judgment is one hour should be sufficient for emergency response organizations and trained personnel to effect positive action to mitigate inundation effects on loss of life.

In terms of acceptable risk relative to inundation, no attempt has been made to segregate risk levels. Recommendations relative to land use in areas subject to possible inundation in the event of a dam failure are presented in Section VII.

C. Seismic Hazards

In this study, primary seismic hazards encompass both potential ground rupture and ground shaking. Although these two seismic hazards are obviously related, for purposes of better problem definition, each has been discussed separately below:

1. Surface Rupture

From analysis presented in the Technical Report, the Sierra Madre, Duarte, and Lower Duarte faults must be considered capable of generating surface rupture. These faults should be thought of in terms of a zone rather than a single fault trace. Consistent with this concept, Plate I, shows identified "Hazard Management Zones" 1/8 of a mile wide on either side of the most active or projected active trace of each fault. It is within this Hazard Management Zone that each fault or fault zone can be considered to exist. Each fault zone occurring within the Hazard Management Zone, most likely does not encompass the entire Hazard Management Zone, however, this approach is consistent with current Alquist-Priolo legislation and work being performed by the California Division of Mines and Geology in regard to active and potentially active faults (refer to Technical Report - Appendix B).

The Hazard Management Zone should be thought of in terms of a special area requiring future geological investigation to determine the exact location and lateral extent of potential ground rupture. Such studies should be made consistent with guidelines established for conducting Alquist-Priolo Geologic Hazard Zones investigations (Technical Report - Appendix B).

For purposes of discussing potential ground rupture relative to land use (Section VII), we have referred to the entire Hazard Management Zone (HMZ) in the land use matrix. This zone (HMZ) should be considered a separate zone apart from the ground shaking and slope instability zones as shown on Plate I. The discussion of acceptable risk under ground motion is applicable to the problem of ground rupture.

There are no known areas of potential ground rupture within the City of Industry. Therefore, no Hazard Management Zones have been designated within the City in this element. The Hazard Management Zones discussed are to the north, in the City of Azusa, as shown on Plate I. Should an active fault be discovered within the City, future investigations should be consistent with the Alquist Priolo Act governing Geologic Hazard zones.

2. Ground motion

The technical analysis of earthquakes to be expected from faults effecting the study area has defined these events in terms of magnitude and recurrence interval. The level of risk associated with each event is indicated by the recurrence interval in much the same manner as the risk from other natural hazards, such as flooding, is defined by a recurrence interval. For example, it is common practice to design flood-prevention works to accommodate the flows from a 100-year storm. Where a higher level of protection is desired, as for example along the Los Angeles River, the design levels are increased to accommodate the flows from storms occurring at roughly 300-500 year intervals.

The choice of a particular earthquake, for which protection is to be provided, involves a determination of acceptable risk. In general, the risk of occurrence decreases as the magnitude of the potential earthquake increases. Since the cost of providing protection increases as the magnitude of the "design earthquake" is increased, there is a point at which the cost of providing protection becomes prohibitive when considered in the light of the cost involved. The 100-year event should be the minimum design standard; where a higher level of protection is desired, such as for hospitals, design levels should be increased to protect against earthquakes with longer recurrence intervals.

The City of Industry is primarily concerned with the Sierra Madre, San Andreas, and Whittier faults. Design magnitude for three levels of "use" for earthquakes expected from these faults is as follows:

Use	Approximate Recurrence Interval (years)	Fault (Source of Earthquake) Sierra Madre	Whittier	San Andreas
		(Richter Magnitude)		
Limited Occupany (warehouses, automated manufacturing facilities etc.)	50-100	--*	4.5	8.5
Normal occupany (residences, normally occupied factories, etc.)	100-200	6.5	5.2	8.5
Critical facilities (hospitals, fire and police stations, schools, critical utilities, etc.)	300-800	7.5	6.0	8.5

* Seismic history of the Sierra Madre fault suggests that smaller earthquakes will probably not occur on this fault.

Based upon analysis presented in the Technical Report relative to these faults, the above events shall be utilized as a minimum design in determining "acceptable risk" in the City of Industry.

The risk of an earthquake on the San Andreas fault is a special case since a major event is considered imminent. As a result, all structures except possibly limited occupancy should be designed for an earthquake of magnitude 8.5 on the San Andreas fault.

These probable earthquakes are presented in terms of seismic zonation, ground motion, and design criteria (response spectra) in the Technical Report. The results point out varying degrees of unacceptable risk throughout the study area and demonstrate the need for modification of the Building Code as it now exists for critical facilities in all of the seismic zones. The response spectra should be analyzed by a structural engineer to determine the appropriate modifications to the City of Industry building code.

These events listed above are design earthquakes which define a hazard. The representatives of the public must ultimately decide on the level of risk they deem acceptable for each type of hazard. This is accomplished by determining the type of facilities that would fall under each of the occupancy classifications relative to these facility classifications are detailed under the Relationship to Land Use section of this report.

The following taxonomy of Critical Facilities is intended for use as a guide in evaluating the importance of each facility relative to overall public safety in terms of fire, inundation, and seismic hazards.

TAXONOMY OF CRITICAL FACILITIES

	Potential Effect on Loss of Life	Required for Community Functioning
Dams	X	
Electrical Sub-Stations		X
Schools/Colleges	X	
Fire Stations		X
Railroad Lines		X
Aqueducts/Pipelines	X	X
Utility Lines		X
County Buildings	X	
City Buildings	X	
Hospitals	X	X
Sewage Treatment Plants		X
Water Works		X
Radio Stations		X
Television Stations		X
Microwave Stations		X
Highway Patrol/Sheriff/ Police Offices		X
Major Highways/Bridges	X	X
Highway Tunnels	X	X
Power Plants (Nuclear)	X	X
Power Plants (Fossil Fuel)		X
Civil Defense Quarters		X
Theatres/Auditoriums and other places of public assembly with over a 100 person capacity	X	

III. HAZARD REDUCTION

A. Fire and Inundation Hazards

The most effective step in reducing fire hazard would be for the County Fire Department to initiate an education campaign. Such a campaign should principally be directed toward the elementary school age group as this group has been responsible for starting many disastrous fires in the past. Openhouse displays and fire fighting demonstrations have proven particularly effective in impressing younger children as well as the general public, with the force and dynamics of fire.

Other actions effective in reducing fire hazards include: firebreaks, special construction, brush-removal, off-road vehicle inspection, and water re-use programs.

Except for the construction of earthquake resistant dams, substantial reduction of inundation potential is difficult to accomplish because of the extent and patterns of urbanization. Determination of "acceptable risk" governs land use/development restrictions in undeveloped areas subject to inundation. In areas already developed, hazard reduction methods must be employed.

The most effective method of hazard reduction is the design and construction of dams to accommodate any probable seismic force and secondary hazard that may occur at the dam site. The other major hazard reduction program involves strengthening of existing community emergency preparedness programs to efficiently evacuate those areas that lie within the inundation boundaries.

B. Seismic Hazards

The City of Industry is a contract City and thereby attains many services from Los Angeles County. For instance, all structural analysis and the enforcement of building codes is carried out by the Los Angeles County Building and Safety Department. The Los Angeles County Building Code, 1971 Edition, is the code adopted by the City. Two basic concepts should be considered in the upgrading and enforcing of building codes involving seismic risk.

First, the primary role of government as related to seismic hazards is to prevent loss of life or serious injury to its citizens. To implement this concern, the city should develop, adopt and enforce a code for the design and construction of new structures that will protect, at an acceptable level of risk, against death or serious injury. A structure which is not a critical facility (critical facilities are a separate issue) has performed well in an earthquake if no one is killed or seriously injured. The structure may be so damaged that it is a total loss to the owner, but it is a success from the standpoint of public safety

if there are no serious injuries. By this concept, the role of government is limited to providing for public safety. Any additional cost required to protect the structure would be at the owner's discretion.

An alternative concept is suggested by events following the San Fernando earthquake in which certain governmental agencies provided funds for repair of damaged structures. In many cases, it has not been necessary to repay a part of these funds, and the public as a whole has accepted at least a part of the cost of repairing structures that were underdesigned for the area in which they were built. If the public does not wish to accept the responsibility of potential federal spending, it could require that structures be designed to a level that would include protection against significant damage. This would be done on the assumption that if the public does not require appropriate design criteria, then they may have to pay the cost of repairing structures built in more hazardous areas.

The Second basic concept is that certain critical facilities such as hospitals, fire and police stations, and communications centers will be required to function at peak efficiency in the hours immediately following a damaging earthquake. The level of protection desirable for a home or an office building may not be adequate for the structures in which these necessary services are housed.

During the hours immediately following the San Fernando earthquake, most of the hospitals in the immediate area could not function because of damage, communication facilities at critical locations were not operative, and fire, police and ambulance service were severely restricted. This experience emphasized the need to function in the hours immediately following a damaging earthquake (e.g., hospitals and communication facilities), or because of an overall requirement that the facility continue to operate (e.g., important governmental buildings).

Increased protection for critical facilities can be applied in two ways. One approach is to require that the structure be designed for an earthquake with a lower risk of occurrence. Critical facilities would be designed to withstand more intense shaking than non-critical facilities.

A second approach is related to "design level," an issue discussed previously. Buildings, such as hospitals, must not only remain intact, but must also continue to function in a manner such that potential victims of an earthquake can be treated. This not only requires a stronger building, but also greater attention to non-structural items such as elevators, lighting fixtures, stability of storage cabinets, etc. This differs from the first approach in that emphasis is placed on usability of the facility after the design seismic event.

In areas subject to potential ground rupture, the placement of critical facilities must be considered with great care so as not to construct across or directly astride an active fault trace. The key concern here is that mitigation of actual ground rupture through building design is questionable and, in most cases, considered impossible if displacement on the order of a few feet is anticipated.

Increased protection for critical facilities is a matter of public policy requiring public involvement at the decision stage and implementation encodes and ordinances by the elected representatives of the people. Public schools and hospitals are reviewed by the State Office of Architecture and Construction or the Division of Mines and Geology, but design criteria for other facilities are determined by local jurisdictions.

Working under the seismic parameters as presented in the Technical Section and as discussed under the "Risk" Section, a systematic inspection and structural analysis of existing structures in the City of Industry should be undertaken. Such a program should be under the direction of the City Engineers office and coordinated with Los Angeles County Department of Building and Safety. The most important existing structures are, of course, critical facilities and those designated a public buildings. Structural evaluation should begin with these buildings.

For existing structures that are non-critical in nature, Table A (abridged from Pacific Fire Rating Bureau) shows relative damagability of varying structural types. This table can be used as a general indicator in older construction to establish a priority ranking for evaluation of non-critical structures. As an example, buildings with a high susceptability to damage rating (five or over) should be selected for structural inspection before those with low ratings.

C. Structural Hazards

Based upon the response spectra for each seismic zone, a review of the Uniform Building Code, 1973 edition, Seismic Design Requirements have been made. Two approaches were taken. The first was through engineering judgment to apply a multiplier to Uniform Building Code seismic design forces for each seismic zone; the second was a conceptual approach to code revision for upgrading lateral force requirements based upon "use". Specific recommended code changes for seismic design should come from a code change committee made up of a seismologist, a geologist, a professional engineer and the city building official. The code change committee function for changes to the Uniform Building Code is currently and continually being performed by the International Conference of Building Officials and the Structural Engineers Association. The City of Industry's adoption of any suitable code change will in no way interrupt the current code change activity and will not reduce

TABLE A

HAZARD COMPARISON OF NON-EARTHQUAKE-RESISTIVE BUILDINGS

Simplified Description of Structural Type	Relative Damagability (in order of increasing susceptibility to damage)
Small wood-frame structures, i.e. dwellings not over 3,000 sq. ft. and not over 3 stories	1
Single or multistory steel-frame buildings with concrete exterior walls, concrete floors, and concrete roof. Moderate wall openings	1.5
Single or multistory reinforced-concrete buildings with concrete exterior walls, concrete walls, and concrete roof. Moderate wall openings	2
Large area wood-frame buildings and other wood frame buildings	3 to 4
Single or multistory steel-frame buildings with unreinforced masonry exterior wall panels; concrete floors and concrete roof	4
Single or multistory reinforced-concrete frame buildings with unreinforced masonry exterior wall panels, concrete floors and concrete roof	5
Reinforced concrete bearing walls with supported floors and roof of any material (usually wood)	5
Buildings with unreinforced brick masonry having sand-line mortar; and with supported floors and roof of any material (usually wood)	7 up
Bearing walls of unreinforced adobe, unreinforced hollow concrete block, or unreinforced hollow clay tile	Collapse hazard in moderate shocks

This table is intended for buildings not containing earthquake bracing, and in general, is applicable to most older construction. Unfavorable foundation conditions and/or dangerous roof tanks can increase the earthquake hazard greatly.

the flexibility and function of this policy report. The geological and structural review has been keyed to critical facilities using criteria summarized in Table 6 of the Technical Report. In no cases have any buildings been inspected for this report. This structural analysis has also focused only on the ability of a structure to protect the occupants of that structure. Historically, the purpose of the earthquake provisions of the building code have been to prevent loss of life, not to prevent damage to the structure. In no case should any conclusions reached in this analysis be extended to include the potential range of damage to structures themselves. Conclusions pertinent to existing structures relative to the Uniform Building Code for critical facilities follows:

1. Existing Structures

Among buildings constructed prior to approximately 1948, wood frame structures two stories or less should be considered safe. Other buildings constructed before 1948 should be considered suspect. In all cases, unreinforced masonry buildings should be considered hazardous. In the absence of detailed structural evaluations, all masonry building constructed prior to 1933 should be considered dangerous.

For existing pre-1948 structures that have been labeled as "critical facilities," such as schools and hospitals, there should be a detailed investigation to determine the structural integrity of the building. For all structures, special attention should be given to such questions as the anchorage of the roof and floor to the walls, the walls to the foundation, the anchorage of the chimney to the roof framing, the anchorage of exterior ornamentation, parapets and roofing tiles to the structure and the amount of discontinuity in the structural framing of each building. During the recent Managua earthquake, it was found that the collapse of suspended ceilings presented additional hazards to occupants.

2. Future Structures

Comparison of the response spectra in the Technical Report with earthquake provisions of the Uniform Building Code, 1973 edition, indicates additional lateral force design requirements are needed. The following chart summarizes these conclusions.

Seismic Zone	Design Force Multiplier to UBC Seismic Zone III	Priority for Modifications to UBC
IVB	1.5	Medium
IVA	1.1	Low
IVC	1.1	Low
VA	1.1	Low
VB	1.1	Low
VC	1.1	Low

A second approach involves establishment of a "use factor" (u) based on the occupancy of the building and applying it to existing lateral force requirements in the code. Utilizing a use factor does not delete or alter any existing design requirements, rather the "use factor" expressed as a multiplier builds upon the present code acknowledging the fact that "occupancy" is as significant as "type of construction" or "structural systems" when establishing the lateral force design requirement of a building.

The following is a suggested breakdown by occupancy group utilizing the use factor (u) as a multiplier to increase the lateral load resisting capacity of buildings with higher occupancy levels and critical facilities.

UBC Occupancy Designation	Use	Use Factor (u)
A,B,C,D	assembly bldgs. stadiums theaters schools hospitals	1.5
E,F,G	work shops service stations storage garages stores office bldgs. municipal bldgs. power plants factories warehouses	1.25
H	hotels apartments condominiums	1.1
I,J	dwellings private garages tanks & towers	1.0

An additional refinement under this approach would be a further breakdown of the groupings such as critical facilities within municipal buildings of the E,F, & G group could have an additional multiplier for fire stations, police facilities and communication centers.

After structural evaluation is completed, critical facilities shown to be of inadequate construction should be scheduled for demolition or reinforcement on a priority basis. If it is not economically feasible to provide an adequate level of protection by strengthening a structure, a lower level of occupancy may be desirable. If many high-risk structures are located in one area, redevelopment may be a solution.

Owners of existing commercial and residential buildings with occupancy capacities in excess of 100 persons, with obvious structural weaknesses should be notified of the conditions so appropriate repairs can be effected. In cases where the private owner is reluctant to take appropriate actions or where the costs of repairs are prohibitive, the City should at least take measures to protect the general public.

A program of this type is not without many social and economic problems and may require several years to complete. A reasonable time interval for completion of such a structural analysis program of existing buildings would be five years. As previously discussed, earliest attention should be given to critical facilities. Their ability to function immediately after an earthquake will affect all of the citizens of the City of Industry, and they should receive the highest priority.

In considering future construction relative to secondary hazards, prime emphasis should be placed upon communicating to developers and builders the findings of this report. The problem of potential liquefaction (Plate I) shall be handled on a site-by-site basis by a licensed Soils Engineer.

D. General Programs for Improving Seismic Safety

Two major programs should result from the Seismic and Public Safety Elements. Implementation of the Public Safety and Seismic Safety Element and the formulation of an Emergency Disaster Plan.

1. Earthquake Disaster Plan

An Emergency Disaster Plan should be formulated which would enable the City to be self-sufficient in the weeks following a severe earthquake, such as a magnitude 7.5 event on the Sierra Madre fault.

This Emergency Disaster Plan should provide for emergency medical facilities, temporary shelter, emergency communications equipment, and emergency water and food supplies. Since a large earth-

quake will severely affect many cities and hundreds of thousands of people, the efforts of Federal and State emergency services will be severely overextended. It is advisable that the City of Industry be prepared to serve itself and maintain continued functioning of necessary services rather than expecting adequate aid from outside organizations.

2. Public Awareness

A program to increase public awareness of earthquake fire and inundation safety should be initiated. The program could be presented as a series of Community meetings or seminars. It should stress minimizing hazards in the home, and precautions to be taken after the occurrence of the earthquake. As an example, Appendix A (from California Geology, 1971) presents a comprehensive list of actions that an individual can take to minimize injury and loss in the event of an earthquake.

E. Plan Update

In utilizing this study and adopting a Safety and Seismic Safety Element, the City must provide the updating and continuance mechanisms necessary for improving safety standards of the community. As part of this process, a monitoring and surveillance system which utlizes information developed by the various state and federal agencies as well as colleges and special interest groups should be established. It is suggested that representatives of the City work with this monitoring system analyze information and relay pertinent findings.

Soil analysis for new structures on a site-by-site basis will be necessary in areas of potential liquefaction and other secondary hazards. Structural evaluation of existing facilities shall also be performed. This is a part of plan update and information base expansion which should be considered for heuristic improvement of decision making related to Seismic Planning. A program of major policy update should be undertaken by the City as technical advancements dictate. In the event of a change in the base data caused by a major earthquake, it may be necessary to formulate a regional study group such as has been undertaken in the technical analysis to reformulate or reconsider this plan and its implications.

IV. GOALS

Safety and Seismic Safety Element goals are a direct statement of community wide aspirations.

Allocation of resources toward achievement of these goals will provide a positive impetus to implementation of the hazard reducing policy set forth herein. The achievement of these goals can be met in numerous ways. The policies of this element when implemented will provide for disaster planning and emergency preparedness in a manner consistent with the Land Use and Circulation Elements of the General Plan of the City of Industry. When a severe disaster occurs within or affecting the City of Industry it will be up to the citizenry to make many of the decisions necessary for the saving of life and property. Government can help - but it cannot do so without the consent and assistance of its citizens. It is unreasonable to expect that government can do the job alone.

General Goals

A. Prevention of serious injury and loss of life

The 1933 Long Beach Earthquake and the 1971 San Fernando Earthquake have taught us many lessons in disaster preparedness, building safety, and hazard prevention. The conclusions presented in this report are based, in part, on the knowledge gained from those experiences.

Personal injury and loss of life can be reduced in an earthquake. One of the most obvious ways to cut down earthquake "risk" is to design structures to accept a "reasonable" amount of ground shaking without incurring structural damage sufficient to cause collapse. Loss of life and prevention of serious injury is a primary responsibility of local government and is of highest priority in the City's safety program.

B. Prevention of serious structural damage to critical facilities

Hospitals, communication facilities, public facilities, schools, and other critical facilities should be designed to function after an earthquake. Action to be taken in regard to these structures will depend upon the "acceptable risk" that a community is willing to accept.

C. Continuance of vital services and functions

This goal is most important in any disaster. It is one of the most important functions of government simply because there is unlikely to be any other organized source of leadership in a major disaster.

Emergency preparedness will include provisions for food, water, and shelter in disasters, fire control and prevention, flood control measures, emergency medical care, police protection, utility services, and disease prevention measures. Responsiveness to secondary hazards in an earthquake may be more important than the actual earthquake damage itself. An example is the potential Van Norman Dam disaster after the initial San Fernando Earthquake in 1971. It is estimated that over 80,000 people were living or working below the dam. Had the dam broken, then the disaster would have been far more severe than it was. In order to insure the continuity of vital services, "planning ahead" is essential.

D. Education of the Community

This goal is a necessary ingredient to the success of any planning effort. It is a role to be played by school districts, public agencies, business firms, and other civic minded individuals who have any interest in the safety programs of their communities.

V. POLICY

A. Public Safety Policy

The following represents a summary of the important findings in the Technical Report of the Safety Element.

Policy Statement

1. Review and evaluate proposed land uses in "extreme" and "high" fire hazard areas as to their vulnerability to fire and their potentiality as ignition sources.

2. Prohibit the use of untreated shake roofs in areas designated as "high" or "extreme" fire hazard.

3. Continue to support programs to reduce fire hazards of vegetation in areas of "extreme" or "high" fire risk. Such programs may take a variety of forms, but may include weed and brush removal and control and use of fire retardant plantings.

4. Expand and intensify precautionary measures regarding industrial activities in "medium" and "high" fire hazard areas. Such measures should include adequate shielding and the implementation of brush-removal programs.

5. Encourage the Los Angeles County Sheriff Department to adopt rigid inspection standards for off-road vehicles (muffler and spark arrester controls) and to closely control the usage of off-road vehicles during periods of high fire risk (low humidity and easterly winds).

6. Encourage the initiation of educational programs through the Los Angeles County Fire Department using displays and demonstrations that would expose younger children to the nature and strength of fire. Such programs would tend to replace their natural curiosity with a sense of respect.

7. Encourage the sponsoring by industries and the Fire Department of exhibits and presentations in secondary schools which demonstrate the more involved aspects of fire dynamics, i.e., major contributing factors to fire hazard and the relationship of fire to the natural ecology. Encourage parental cooperation and assistance in overall fire education programs.

8. Investigate water re-use programs in the hillside areas to aid in fire prevention.

9. Encourage the improvement of power and gas line inspections and new installations through a coordinated effort between Southern California Edison, Southern California Gas Company and Los Angeles County Fire Department.

10. Encourage the Fire Department to adopt special inspection criteria in those areas of "extreme", "high", and "medium" fire risk during critical fire season when the sustained wind velocity exceeds 25 miles per hour.

11. Encourage and support continuing "mutual assistance" agreements between the fire departments of the local cities, Los Angeles County and Angeles National Forest.

12. Improve Civil Defense capabilities for emergency evacuation and mobilization efforts.

13. Encourage the County Building and Safety Department to inspect dams and evaluate dam safety requirements.

14. Investigate siting of future critical facilities only in those areas beyond the 60 minute line that signifies the time between dam failure and inundation.

15. Make available Technical Report findings to developers, industries, and appropriate civic groups.

16. Evaluate the impact on land use which results from "stacking" of multiple hazard zones.

17. Encourage programs that train volunteers to assist police, fire, and civil defense personnel effectively after a natural disaster.

18. Section 11525 of the Business and Professional Code and Section 65401 of the Government Code relating to subdivisions require that all developments be submitted for governmental review. The City should enforce this provision taking into account recommendations from the Safety Element report.

B. Seismic Safety Policy

The State of California considers the threat of earthquake serious enough to require a Seismic Safety Element in the General Plan of all incorporated governmental bodies. At the same time, it should be realized that the threat of earthquake is not the same at all times or in all places. This Seismic Safety Element traces the impact of probable earthquakes on the City of Industry. The preceding discussions indicate that the City can initiate many actions to counter these anticipated impacts. The most important implications of seismic safety are in terms of building and disaster preparedness. The following represents a summary of the important study findings.

Policy Statement

1. Adopt the current Los Angeles County Building Code.

2. City of Industry Ordinance No. 301 (grading) should be strengthened to require geological and soils engineering investigations in moderate and high landslide risk, potential liquefaction and subsidence areas and critical seismic zones such as those where ground acceleration values exceed the current LACBC Standards.

3. The City shall make the technical information presented herein available to the County Building and Safety Department which has the responsibility of all structural inspections and approvals within the City of Industry. Building and Safety should review the County Building Code to determine if changes are necessary due to expected seismic conditions resulting from future earthquakes.

4. A program of building inspection should be initiated to identify all structures in the City that do not meet modern earthquake standards for construction and conform to design criteria of the adopted City building code.

5. The City should establish and implement a program for the orderly elimination of hazardous old buildings.

6. The Technical Section of the Seismic Safety Element should be made available to developers for review and use when proposing land development.

7. A building strong-motion instrumentation program should be instituted for buildings over four (4) stories in height with an aggregate floor area of 40,000 square feet or more, and every building over six (6) stories in height regardless of floor area.

8. Emergency communication centers, fire stations, and other emergency service facilities should be examined as to their earthquake resistant capacities. If found below acceptable standard, a program to mitigate potential hazards should be immediately established.

9. All critical facilities constructed prior to 1948 should be reviewed by a structural engineer for potential hazards. High pressure natural gas, petroleum, and electrical power transmission lines should be reviewed for safety and land use compatibility.

10. New construction directly astride or across known active faults, or fault zones, should be prohibited. Non-structural land uses, however, should be permitted.

11. A program to effectively lower the groundwater in the potential liquefaction areas to at least thirty feet below the surface should be evaluated immediately.

12. Encourage programs that train volunteers to assist police, fire, and civil defense personnel effectively after an earthquake.

13. Division 1 and 2 of Part 2 of Title 7 planning and land planning use section of the Government Code relating to subdivision zoning ordinances require that all developments be submitted for governmental review. The City should enforce this provision taking into account recommendations from the Seismic Safety Element.

14. Establish a priority system of evacuation routes and critical services to be provided in the event of an earthquake disaster.

15. Evaluate land use impacts resulting from "stacking" of multiple hazard zones.

16. Establish a Disaster Preparedness Program for the City of Industry. Objectives of the program should be:

    a. To save lives and protect property.

    b. To provide a basis for direction and control of emergency operations.

    c. To provide for the continuity of government.

    d. To repair and restore essential systems and services.

    e. To provide for the protection, use and distribution of remaining resources.

    f. To coordinate operations with the civil defense emergency operations or other jurisdictions.

17. Federal, State and County agencies should be encouraged to intensify research on seismic and other geologic hazards.

18. The Seismic Safety Element shall be reviewed by the City Planning Department annually and a program of major policy revisions should be undertaken whenever substantially new scientific evidence becomes available.

VI. IMPLEMENTATION PROCEDURES

A. Public Safety

1. EDUCATION

- Make available to builders and realtors findings of the Safety Element.
- Encourage State, Federal, and County agencies to intensify research on flood and inundation hazards.

2. GENERAL PLAN

- Relate findings of Safety Element to Open Space, Land Use, Circulation, Housing, and Scenic Highways Plans.
- Public Utilities and Municipal Agencies should review the Safety Element for determination of impact on storage and transportation facilities including gas, electricity and communication transmission facilities, water tanks, and major distribution/transformation network centers.
- Union and Southern Pacific Railway Companies should review the Safety Element with respect to possible impact on their transportation, storage, maintenance and station facilities.

3. ORDINANCES

- Review subdivision requirements and make recommendations to the City Council and Planning Commission on implications of the Safety Element.
- Review and update, as necessary, the grading ordinance and pertinent administrative procedures.
- Review the zoning ordinance and make any desired changes such as requirement of fire retardent roofing materials in areas of high and extreme fire risk.

4. EMERGENCY SERVICES PROGRAM

- Implement emergency service requirements of Safety Element in a declared disaster and coordinate activities of police, fire, civil defense and volunteer activities.
- Encourage Public Safety disaster information release programs for use in emergencies.
- Restructure emergency services programs to include plans to deal with inundation in the event of dam failures.

B. Seismic Safety

1. EDUCATION

- Make available to builders and realtors findings of the Seismic Safety Element.

- Encourage Federal, State, and County agencies to intensify research on seismic and other geologic hazards, with particular attention to expanding research with respect to the Alquist/Priolo zones.

2. GENERAL PLAN

- Relate findings of Seismic Safety Element to Open Space, Land Use, Circulation, Housing, and Scenic Highways Plans.

- The California Department of Water Resources should review the Seismic Safety Element and forward comments regarding dams to the City public services director.

- Caltrans should review the Seismic Safety Element with respect to freeways and other major highways and forward comments to the City. The circulation elements should then be revised, if necessary.

- Public Utilities and Municipal Agencies should review the Seismic Safety Element for determination of impact on storage and transportation facilities including gas, electricity and communication transmission facilities, water tanks, and major distribution/transformation network centers.

- Union and Southern Pacific Railway Companies should review the Seismic Safety Element with respect to possible impact on their transportation, storage, maintenance, and station facilities.

3. ORDINANCES

- Review subdivision requirements and make recommendations to the City Council and Planning Commission on implications of the Seismic Safety Element and make desired changes.

- Review and update as necessary grading ordinances and pertinent administrative procedures.

- Review the zoning ordinance and make any desired changes including requirement of geologic and soils reports in moderate and high landslide risk, potential liquefaction and subsidence area, and critical seismic zones with the objective to insure public safety.

- Establish procedures for dealing with geologic reports and investigations particularly when critical facilities are involved.

4. EMERGENCY SERVICES PROGRAM

- Implement emergency service requirements of Seismic Element in a declared disaster and coordinate activities of police, fire, civil defense and volunteer activities.

- Prepare geologic disaster information release programs for use in emergencies.

VII. RELATIONSHIPS TO OTHER GENERAL PLAN ELEMENTS

A. Land Use

Base on analysis of potential seismic, fire, and inundation hazards, recommendations in matrix form are presented for building type/land use with respect to each type of hazard zone. The decisions reached in preparing such recommendations are subject to the public decision making process in the same manner as is the concept of "acceptable risk". The judgments are, however, intended as statements of planning consideration relative to future land use in each hazard zone.

In reviewing the recommendations expressed in the matrix several concerns should be recognized:

There are no known active faults transecting the City of Industry, if some are subsequently determined to be present, construction should be prohibited directly atop or astride these faults. It should be the responsibility of the City Engineer together with the County Building and Safety Department to establish a reasonable building setback distance based on future detailed geological studies of any new faults within the City. Such studies can either be conducted by the City or by the sponsor of individual development projects. If studies are to be conducted by individual land developers, then work should be completed prior to, or at the EIR stage. Guidelines for such studies should be those set forth by the State Mining and Geology Board with reference to the Alquist-Priolo Geologic Hazard Zones Act (Technical Report - Appendix B).

Critical facilities to be constructed within the City of Industray shall not be placed within areas subject to liquefaction or inundation (within 60 minutes of dam failure).

Land use controls may be established for those zones in which the effect of "stacking" (combination of individual natural hazard zones) results in a high level of overall hazard as determined by analysis of the zones as they relate to the hazard categories.

B. Housing

The Technical Report findings indicate restrictions should be placed on housing construction in at least the areas of extreme fire hazard and high slope instability. Lesser restrictions include prohibiting untreated wood shake roofs in transition zones between the valley and hillside areas, strengthening or replacing seismically unsafe structures, and requiring all new construction to be in conformance with seismic modifications of the City building code.

	BUILDING TYPE/LAND USE	SEISMIC, FIRE, INUNDATION, AND SECONDARY HAZARDS ZONES (SHOWN ON PLATES 8 11)																
		IVA	IVB	IVC	VA	VB	VC	HMZ	C1	C2	C3	E	H	M	L	I*	A1**	B1**
CRITICAL FACILITIES	Power Plants (nuclear, fossil fuel, large dams, Civil Defense Headquarters, Major Electrical Facilities.	⊙	○	⊙	⊙	○	⊙	⊗	○	⊘	⊘	⊘	⊘	○	⊙	⊗	⊘	⊘
	Power Communication sub-stations, Hospitals, Schools, Fire/Police offices, Radio/TV/Microwave stations, Major Highways/Bridges/Tunnels/Aqueducts/Pipelines, Public Buildings, Theatres/Auditoriums, Sewage Treatment Plants, Water Works, utility Lines, Railroad Lines.	⊙	⊙	⊙	⊙	⊙	⊙	⊗	⊙	○	⊘	⊘	○	○	⊙	⊘	⊘	⊘
NORMAL FACILITIES	Office Buildings, Commercial Centers, Hotels/Motels, Heavy Industrial, Minor Public Buildings, Most Roads, Gradecrossings, Minor Utility Operations.	⊙	⊙	⊙	⊙	⊙	⊙	⊘	⊙	○	⊘	⊘	○	○	⊙	○	⊘	⊘
	Residential Housing (Attached/Detached) Single Family, Apartments, Condominiums, Townhouses.	⊙	⊙	⊙	⊙	⊙	⊙	⊘	⊙	○	⊘	○	○	○	⊙	○	⊘	⊘
LIMITED FACILITIES	Light Industrial/Commercial Factory/Warehousing operations, Service Stations, Large Recreational Parks, Managed Mineral Resource Development.	⊙	⊙	⊙	⊙	⊙	⊙	○	⊙	○	⊘	○	○	○	⊙	○	○	○
	Regional/Community Parks, Minor Recreational Centers, Open Space, Refuse Disposal sites, Agriculture.	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙

Explanation

⊙ Generally Suitable ○ Provisionally Suitable ⊘ Generally Unsuitable ⊗ Restricted

Notes: This Chart is for General Land use planning only. Suitability for specific uses for a specific site must be confirmed by further investigation. An area evaluated as generally unsuitable for a particular use does not necessarily preclude the use, if no other suitable alternative sites are available, and provided that all potential hazards can be mitigated. In the case of restricted areas, mitigation is extremely difficult and in some instances, impossible.

*For purposes of this evaluation, flood inundation includes those geographical areas capable of being inundated with flood waters within sixty (60) minutes of a dam failure.

**Requires further evaluation by soils engineer on a site-by-site basis.

C. Open Space

Areas with known hazards should be considered for Open Space zoning, typical hazards include lands designated as extreme fire risk, active landslides, high slope instability, the flood plains directly below the nearby dams and any fault zones subsequently designated within the City of Industry.

D. Circulation/Transportation

The circulation network, principally freeway overpasses and rail grade separations will be hard hit in the event of moderate to large earthquake on the Sierra Madre fault system. The effects expected will be similar to what occurred in the Sylmar-San Fernando Valley area in the 1971 earthquake. The response spectra presented in the Technical Report of the Seismic Safety Element should be used by structural engineers in the evaluation of existing freeway overpasses and other important grade separations. New construction of brdiges, overpasses, etc. should also utilize seismic response design criteria.

Special consideration of expected damage to the circulation network should be anticipated in the community emergency preparedness plan. Based on structural evaluation, assumptions regarding failure of overcrossings, should be made and alternative evacuation and/or supply routes established in the plan.

APPENDIX A

Earthquake Safety Procedures in the Home

EARTHQUAKE SAFETY PROCEDURES

Before an Earthquake

1. Potential earthquake hazards in the home should be removed or corrected. Top-heavy objects and furniture, such as bookcases and storage cabinets, should be fastened to the wall and the largest and heaviest objects placed on lower shelves. Water heaters and other appliances should be firmly bolted down, and flexible connections should be used whenever possible.

2. Supplies of food and water, flashlight, a first-aid kit, and a battery-powered radio should be set aside for use in emergencies. Of course, this is advisable for other types of emergencies, as well as for earthquakes.

3. One or more members of the family should have a knowledge of first aid procedures because medical facilities nearly always are overloaded during an emergency or disaster, or may themselves be damaged beyond use.

4. All responsible family members should know what to do to avoid injury and panic. They should know how to turn off the elctricity, water, and gas; they should know the locations of the main switch and valves. This is particularly important for teenagers who are likely to be alone with smaller children.

5. It is most important for a resident of California to be aware that this is "earthquake country" and that earthquakes are most likely to occur again where they have occurred before. Building codes that require earthquake-resistant construction should be vigorously supported and, when enacted into law, should be rigorously enforced. If effective building codes and grading ordinances do not exist in your community, support their enactment.

During An Earthquake

1. The most important thing to do during an earthquake is to remain calm. If you can do so, you are less likely to be injured. If you are calm, those around you will have a greater tendency to stay calm, too. Make no moves or take no action without thinking about the possible consequences. Motion during an earthquake is not constant; commonly, there are a few seconds between tremors.

2. If you are inside a building, stand in a strong doorway or get under a desk, table, or bed. Watch for falling plaster, bricks, light fixtures, and other objects. Stay away from tall furniture, such as china cabinets, bookcases, and shelves. Stay away from windows, mirrors, and chimneys. In tall buildings, it is best to get under a desk if it is securely fastened to the floor, and to stay away from windows or glass partitions.

3. Do not rush outside. Stairways and exits may be broken or may become jammed with people. Power for elevators and escalators may have failed. Many of the 115 persons who perished in Long Beach and Compton in 1933 ran outside only to be killed by falling debris and collapsing chimneys. If you are in a crowded place such as a theater, athletic stadium, or store, do not rush for an exit because many others will do the same thing. If you must leave a building, choose your exit with

and collapsing walls or chimneys.

4. If you are outside when an earthquake strikes, try to stay away from high buildings, walls, power poles, lamp posts, or other structures that may fall. Falling or fallen electrical power lines must be avoided. If possible, go to an open area away from all hazards but do not run through the streets. If you are in an automobile, stop in the safest possible place, which, of course, would be an open area, and remain in the car.

After An Earthquake

1. After an earthquake, the most important thing to do is to check for injuries in your family and in the neighborhood. Seriously injured persons should not be moved unless they are in immediate danger of further injury. First aid should be administered, but only by someone who is qualified.

2. Check for fires and fire hazards. If damage has been severe, water lines to hydrants, telephone lines, and fire alarm systems may have been broken; contacting the fire department may be difficult. Some cities, such as San Francisco, have auxiliary water systems and large cisterns in addition to the regular system that supplies water to fire hydrants. Swimming pools, creeks, lakes, and fish ponds are possible emergency sources of water for fire fighting.

3. Utility lines to your house - gas, water, and electricity - and appliances should be checked for damage. If there are gas leaks, shut off the main valve which is usually at the gas meter. Do not use matches, lighters, or open-flame appliances until you are sure there are no gas leaks. Do not use electrical switches or appliances if there are gas leaks, because they give off sparks which could ignite the gas. Shut off the electrical power if there is damage to the wiring; the main switch usually is in or next to the main fuse or circuit breaker box. Spilled flammable fluids, medicines, drugs, and other harmful substances should be cleaned up as soon as possible.

4. Water lines may be damaged to such an extent that the water may be off. Emergency drinking water can be obtained from water heaters, toilet tanks, canned fruits and vegetables, and melted ice cubes. Toilets should not be flushed until both the incoming water lines and outgoing sewerlines have been

checked to see if they are open. If electrical power is off for any length of time, plan to use the foods in your refrigerator and freezer first before they are spoiled. Canned and dried foods should be saved until last.

5. There may be much shattered glass and other debris in the area, so it is advisable to wear shoes or boots and a hard hat if you own one. Broken glass may get into foods and drinks. Liquids can be either strained through a clean cloth such as a handkerchief or decanter. Fireplaces, portable stoves, or barbecues can be used for emergency cooking but the fireplace chimney should be carefully checked for cracks and other damages before being used. In checking the chimney for damage, it should be approached cautiously, because weakened chimneys may collapse with the slightest of aftershocks. Particular checks should be made of the roof line and in the attic because unnoticed damage can lead to a fire. Closets and other storage areas should be checked for objects that have been dislodged or have fallen, but the doors should be opened carefully because of objects that may have fallen against them.

6. Do not use the telephone unless there is a genuine emergency. Emergencies, and damage reports, alerts, and other infomation can be obtained by turning on your radio. Do not go sightseeing; keep the streets open for the passage of emergency vehicles and equipment. Do not speculate or repeat the speculations of other - this is how rumors start.

7. Stay away from beaches and other waterfront areas where seismic sea waves (tsunamis), sometimes called "tidal waves", could strike. Again, your radio is the best source of information concerning the likelihood that a seismic sea wave will occur. Also stay away from steep landslide-prone areas if possible, becuase aftershocks may trigger a landslide or avalnche, especially if there has been a lot of rain and the ground is nearly saturated. Also stay away from earthquake-damaged structures. Additional earthquake shocks known as "aftershocks" normally occur after the main shock, sometimes over a period of several months. These are usually smaller than the main shock but they can cause damage, too, particularly to damaged and already weakened structures.

8. Parents should stay with young children who may suffer psychological trauma if parents are absent during the occurrence of aftershocks.

9. Cooperate with all public safety and relief organizations. Do not go into damaged areas unless authorized; you are subject to arrest if you get in the way of, or otherwise hinder, rescue operations. Martial law has been declared in a number of earthquake disasters. In the 1906 disaster in San Francisco, several looters were shot.

10. Send information about the earthquake to the Seismological Field Survey to help earth scientists understand earthquakes better.

APPENDIX B

Safety Element Guidelines

1. AUTHORITY

Government Code Section 65302.1 requires a safety element of all city and county general plans, as follows:

> A safety element for the protection of the community from fires and geologic hazards including features necessary for such protection as evacuation routes, peak load water supply requirement, minimum road widths, clearances around structures, and geologic hazard mapping in areas of known geologic hazard.

2. THE SCOPE AND NATURE OF THE SAFETY ELEMENT

The objective of this element is to introduce safety considerations in the planning process in order to reduce loss of life, injuries, damage to property, and economic and social dislocation resulting from fire and dangerous geologic occurrences.

A. General policy statement that:

1. Recognizes safety hazards
2. Identifies goals for reducing hazard
3. Specifies the level of acceptable risk
4. Specifies objectives to be attained in reducing safety hazards as related to existing and new structures.
5. Sets priorities for the abatement of safety hazards, recognizing the variable frequency and occurrence of hazardous events.

B. A map showing the location and extent of known geologic hazards.

C. Standards and general criteria for land use and circulation relating to:

1. Fire prevention and control
2. Geologic hazards

D. Consideration may be given to the crime prevention aspects of land use development such as planning for "defensible space".

3. METHODOLOGY

A. Identification, mapping and evaluation of existing and potential hazards, both as to severity and frequency of occurrence. Analysis of hazardous land use relationships.

B. With maximum citizen input "acceptable risk" should be determined. In making this determination, it should be kept in mind that any attempt to develop the appropriate planning

response to potential hazard involves a judgement, either explicit or implicit, of how much risk is acceptable. There is no such thing as a perfectly hazard-free environment. Natural and man-made hazards of some kind and degree are always present. However, efforts can be productively undertaken to try to mitigate the consequences of known hazards.

In the context of the Safety Element, the problem of risk is one of public policy and the appropriate allocation of public resources to mitigate hazards. The central question is, "how safe is safe enough?" The planner's responsibility is to provide a framework in which a communitywide, as opposed to an individual, response to the question can be meaningful. The first of several essential steps is the recognition of the presence of a hazard. Much of the planning of the past has proceeded without enough knowledge of the natural forces at play in a given area.

Once a problem has been recognized, considerable effort is required to evaluate its likely severity, frequency, and the characteristics of the area involved. This step should take into account the benefit/cost ration of reducing hazard, acknowledging the intangibles involved, and comparing it with that of other projects. The factors of voluntary and involuntary exposure to risk must be considered in reaching a decision.

C. Define nature and magnitude of effort requried to correct or mitigate hazards.

D. Define general nature of regulations and programs needed to prevent or mitigate the effects of hazards in the developed and natural environments.

E. Exchange information and advice with fire, police and public works departments, other agencies, and specialty personnel in the formulation of the element.

4. DEFINITION OF TERMS

A. Acceptable Risk: The level of risk below which no specific action by local government is deemed to be necessary.

Unacceptable Risk: Level of risk above which specific action by government is deemed to be necessary to protect life and property.

Avoidable Risk: Risk not necessary to take because individual or public goals can be achieved at the same or less total "cost" by other means without taking the risk.

Defensible Space: Concept of urban space designed to inhibit crime by utilizing the proprietary concerns of residents. Key ingredients in designing defensible space include: improving the natural capability of residents to visually survey the public areas of their residential environment; enhancing spheres of territorial influence within which residents can easily adopt proprietary attitude; and enhancing safety through the strategic geographic location of intensively used community facilities.

5. RELATIONSHIPS OF THE SAFETY ELEMENT

A. To Other Elements:

1. The Safety Element contributes to developing land use standards and policies. These will relate type and intensity of use to the level of risk from fire and geologic hazards, to the effect of development upon that risk, and to the availability of services and facilities to combat them.

   The Safety element also contributes basic standards and requirements to the circulation and optional public utilities elements, and will have important implications for the open space and conservation elements.

2. Because of the strong relationship with the Seismic Safety Element, the local planning body may wish to prepare these two elements simultaneously or to combine the two elements into a single document.

B. To Other Factors:

1. Social: The element is directed at reducing social due to injury, loss of life, or public or private dislocations increasing the sense of community security and well-being.

2. Economic: The element should be directed at reducing costs of direct property loss and economic dislocation.

3. Environmental Impact: The Safety Element provides the policy directives for reducing adverse impacts on both the built and natural environments of major safety hazards.

C. To Other Agencies:

1. The preparation of the Safety Element would also be facilitated by identifying, and securing the cooperation of major Federal, State, regional, and private owners of land in a largely natural state, which affects the potential fire hazard. Such agencies would include, for example, the national and state park services.

2. Local planning bodies are encouraged to enter into joint planning and the execution of mutual assistance pacts related to safety hazards materially affecting more than one planning jurisdiction.

6. IMPLEMENTATION

A. Concurrent or subsequent revision of other general plan elements to incorporate safety policies and criteria.

B. Addition of capital improvements as may be necessary for the mitigation and control of safety hazards to the capital improvement program.

C. Review and possible amendment of zoning, subdivision and site development regulations to incorporate safety provisions.

D. Formulate building and fire safety inspection programs of buildings and premises to identify fire and other safety hazards.

E. Provide input to contingency plans for major disaster or emergencies.

F. Provide for ongoing review of major public and private development proposals by fire and police departments to insure compatibility with safety objectives.

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2. Economic: The element should be directed at reducing costs of direct property loss and economic dislocation.

3. Environmental Impact: The Safety Element provides the policy directives for reducing adverse impacts on both the built and natural environments of major safety hazards.

C. To Other Agencies:

1. The preparation of the Safety Element would also be facilitated by identifying, and securing the cooperation of major Federal, State, regional, and private owners of land in a largely natural state, which affects the potential fire hazard. Such agencies would include, for example, the national and state park services.

2. Local planning bodies are encouraged to enter into joint planning and the execution of mutual assistance pacts related to safety hazards materially affecting more than one planning jurisdiction.

6. IMPLEMENTATION

A. Concurrent or subsequent revision of other general plan elements to incorporate safety policies and criteria.

B. Addition of capital improvements as may be necessary for the mitigation and control of safety hazards to the capital improvement program.

C. Review and possible amendment of zoning, subdivision and site development regulations to incorporate safety provisions.

D. Formulate building and fire safety inspection programs of buildings and premises to identify fire and other safety hazards.

E. Provide input to contingency plans for major disaster or emergencies.

F. Provide for ongoing review of major public and private development proposals by fire and police departments to insure compatibility with safety objectives.

APPENDIX C

Seismic Safety Element Guidelines

1. AUTHORITY

A. Authority

Government Code Section 65302(f) requires a Seismic Safety element of all city and county general plans, as follows:

> A Seismic Safety Element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.
>
> The Seismic Safety Element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure and seismically induced waves.

The effect of this section is to require cities and counties to take seismic hazards into account in their planning programs. All seismic hazards need to be considered, even though only ground and water effects are given as specific examples. The basic objective is to reduce loss of life, injuries, damage to property, and economic and social dislocations resulting from future earthquakes.

B. Background

Earthquake losses in California through the remainder of this century, assuming that additional significant countermeasures are not taken, have recently been estimated at approximately $20 billion (Urban Geology Master Plan, California Division of Mines and Geology). Estimates of potential loss of life for this period range well up into the thousands and most of this loss is preventable.

The most widespread effect of an earthquake is <u>ground shaking</u>. This is also usually (but not always) the greatest cause of damage. Structures of all types, including engineered structures and public utility facilities, if inadequately constructed or designed to withstand the shaking force, may suffer severe damage or collapse. The vast majority of deaths during earthquakes are the result of structural failure due to ground shaking. Most such deaths are preventable, even with present knowledge. New construction can and should be designed and built to withstand probable shaking without collapse. The greatest existing hazard in the State is the continued use of tens of thousands of older structures incapable of withstanding earthquake forces. Knowledge of earthquake-resistance design and construction has increased greatly in recent years, though much remains to be learned.

A second effect of earthquakes is ground failure in the form of landslides, rock falls, subsidence and other surface and near-surface ground movements. This is often the result of complete loss of strength of water-saturated sub-surface foundation soils ("liquefaction"), such as occurred near the Juvenile Hall in the 1971 San Fernando earthquake and in the massive Turnagain Arm landslide in Anchorage, during the 1954 Alaska earthquake. Most such hazardous sites can be either avoided or stabilized if adequate geologic and soil investigations are utilized.

Another damaging effect of earthquakes is ground displacement (surface rupture) along faults. Such displacement of the earth's crust may be vertical, horizontal or both and may offset the ground by as much as 30 feet (as in 1857 in Southern California). It is not economically feasible to design and build foundations of structures (dams, buildings, bridges, etc.) to remain intact across such zones. Fault zones subject to displacement are best avoided in construction. In addition to regional investigations necessary to the basic understanding of faults and their histories, detailed site investigations are needed prior to the approval of construction in any suspected active fault zone. Utilities, roads, canals and other linear futures are particularly vulnerable to damage as the result of ground displacement.

Other damaging effects of earthquakes include tsunamis (seismic sea waves, often called "tidal waves"), such as the one which struck Crescent City and other coastal areas in 1964; and seiches (waves in lakes and reservoirs due to tilting or displacement of the bottom or margin). The failure of dams due to shaking, fault displacement or overtopping (from seiches or massive landsliding into the reservoir) can be particularly disastrous. Most modern dams may be created by earthquake-triggered landslides. Such inadvertently created dams are certain to fail within a relatively short time.

2. THE SCOPE AND NATURE OF THE SEISMIC SAFETY ELEMENT

A. A general policy statement that:

1. Recognizes seismic hazards and their possible effect on the community.
2. Identifies general goals for reducing seismic risk.
3. Specifies the level or nature of acceptable risk to life and property (see safety element guidelines for the concept of "acceptable risk").
4. Specifies seismic safety objectives for land use.
5. Specifies objectives for reducing seismic hazard as related to existing and new structures.

B. Identification, delineation and evaluation of natural seismic hazards.

C. Consideration of existing structural hazards.

Generally, existing substandard structures of all kinds (including substandard dams and public utility facilities) pose the greatest hazard to a community.

D. Evaluation of disaster planning program

For near-term earthquakes, the most immediately useful thing that a community can do is to plan and prepare to respond to and recover from an earthquake as quickly and effectively as possible, given the existing condition of the area. The seismic safety element can provide guidance in disaster planning.

E. Determination of specific land use standards related to level of hazard and risk.

3. METHODOLOGY

As an initial step, it may be helpful to determine what aspects of the element need greater emphasis. If a community is largely developed, emphasis on structural hazards and disaster planning would be most appropriate. This would also be the case for communities whose greatest hazard will be from ground shaking. On the other hand, communities with extensive open areas and areas subject to urbanization may wish to focus on natural seismic hazards and the formulation of land use policies and development regulations to insure that new development is not hazardous.

Additionally, local planning agencies may wish to consider the preparation of the element or portions of the element in joint action. This would be particularly practical for the study of natural seismic hazards.

A. Initial organization

1. Focus on formulating and adopting interim policy based on very general evaluation of earth science information readily available.
2. Evaluate adequacy of existing information in relation to the identified range and severity of problems.
3. Define specific nature and magnitude of work program needed to complete the element in a second stage.

B. Identification of natural seismic hazards

1. General structural geology and geologic history.
2. Location of all active or potentially active faults, with evaluation regarding past displacement and probability of future movement.

3. Evaluation of slope stability, soils subject to liquefaction and differential subsidence.
4. Assessment of potential for the occurrence and severity of damaging ground shaking and amplifying effects of unconsolidated materials.
5. Identification of areas subject to seiches and tsunamis.
6. Maps identifying location of the above characteristics.

C. Identification and evaluation of present land use and circulation patterns should be recognized in the formulation of seismic safety-land use policies.

D. Identification and evaluation of structural hazards relating structural characteristics, type of occupancy and geologic characteristics in order to formulate policies and programs to reduce structural hazard.

E. Formulation of seismic safety policies and recommendations.

F. Formulation of an implementation program.

4. DEFINITION OF TERMS

A. Acceptable risk: The level of risk below which no specific action by local government is deemed necessary, other than making the risk known.

Unacceptable risk: Level of risk above which specific action by government is deemed necessary to protect life and property.

Avoidable risk: Risk not necessary to take because the individual or public goals can be achieved at the same or less total "cost" by other means without taking the risk.

B. Technical Terminology:

Tsunamis: Earthquake-induced ocean waves, commonly referred to as tidal waves.

Seiches: Earthquake-induced waves in lakes or ponds.

Seismic: Pertaining to or caused by earthquake.

Soil Liquefaction: Change of water saturated cohesionless soil to liquid, usually from intense ground shaking; soil loses all strength.

Tectonic, forms, forces, and movements resulting from deformation of the earth's crust: Movement may be rapid resulting in earthquake, or slow (tectonic creep).

Fault: A plane or surface in earth materials along which failures have occurred and materials on opposite sides have moved relative to one another in response to the accumulation of stress in the rocks.

Active Fault: A fault that has moved in recent geologic time and which is likely to move again in the relatively near future. (For geologic purposes, there are no precise limits to recency of movement or probable future movement that define an "active fault". Definitions for planning purposes, extend on the order of 10,000 years or more back and 100 years or more forward. The exact time limits for planning purposes are usually defined in relation to contemplated uses and structures.)

Inactive Fault: A fault which shows no evidence of movement in recent geologic time and no evidence of potential movement in the relatively near future.

Seismic Hazards: Hazards related to seismic or earthquake activity.

Ground Failures: Include mudslide, landslide, liquefaction, subsidence.

Surface ruptures from faulting: Breaks in the ground surface resulting from fault movement.

5. RELATIONSHIPS

A. To other Elements:

The seismic safety element contributes information on the comparative safety of using lands for various purposes, types of structures, and occupancies. It provides primary policy inputs to the land use, housing open space, circulation and safety elements.

Because of the close relationship with the safety element the local planning agency may wish to prepare these two elements simultaneously or combine the two elements into a single document. If combined, the required content and policies of each element should be clearly identifiable. The local jurisdiction may wish to include the seismic safety element as a part of an environmental resources management element - ERME - as discussed previously.

B. To Environmental Factors:

1. Physical: Geologic hazards can be a prime detrimant of land use capability.

2. Social: May provide basis of evaluating costs of social disruptions, including the possible loss of life due to earthquake and identifies means of mitigating social impact.

3. Economic: Cost and benefits of using or not using various areas related to potential damage or cost of overcoming hazard.

4. Environmental Impact Report: Provides basis for evaluating environmental impact of proposed projects in relation to slope stability, possible structure failure, etc.

C. To Other Agencies:

The State Geologist is required by Chapter 7.5, Division 2 of the Public Resources Code to delineate by December 31, 1973, special studies zones encompassing certain areas of earthquake hazard on maps and to submit such maps to affected cities, counties, and state agencies for review and comments.

By December 31, 1973, the Division of Mines and Geology will have delineated the special studies zones encompassing all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults. The special studies zones will be delineated on U.S. Geological Survey quadrangle sheets. The quadrangles listed in Appendix F will be included in the initial distribution which will begin on or about October 1, 1973, and be completed by December 31, 1973. In addition to the faults named above, all active or potentially active faults within the quadrangles listed will be zoned. The zones are ordinarily about one-quarter mile in width.

The State Mining and Geology Board is required by Chapter 7.5, Division 2 of the Public Resources Code to develop policies and criteria by December 31, 1973, concerning real estate developments or structures to be built within the special studies zones.

6. IMPLEMENTATION

A. Concurrent or subsequent revision of other general plan elements to give specific recognition to seismic safety policies and criteria.

B. Inclusion of appropriate requirements and procedures in zoning, subdivision and site development regulations and building codes. Designation of special zones with special land development regulations such as "seismic hazards management zones".

C. Preparation of renewal plans for areas where a change in use and development pattern is necessary because of major seismic damage or extreme hazard.

D. Building inspection program to identify unsafe structures and instigate necessary corrective measures.

E. Inclusion of potential earthquake destruction in contingency plans for major disasters and emergencies. Review and liaison with Emergency Preparedness Organizations and Police Departments of overall plans and major public facilities proposals as to their adequacy in emergency situations.

F. Educational programs to develop community awareness of seismic hazards.

G. Updating the building code to reflect changes in technology.

NOTE: These guidelines drew extensively from:

Suggested Interim Guidelines for the Seismic Safety Element in General Plans, prepared by the Governor's Earthquake Council July, 1972.

Draft Guidelines for the Seismic Safety Element, prepared by Advisory Group on Land Use Planning for Joint Committee on Seismic Safety, California State Legislature, September, 1972.

Seismic Safety Concerns in CIR/OIM Program prepared for CIR by William Spangle & Associates, March 1972, unpublished.

Public Safety and Seismic Safety Elements

Technical Report

Cities of Azusa, Covina, Industry and West Covina

prepared by

ENVICOM CORPORATION

May 1975

SEISMIC SAFETY: Technical Section

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I. INTRODUCTION

A. SCOPE OF INVESTIGATION

Section 65302 (f) of the Government Code requires a Seismic Safety Element of all city and county general plans as follows:

> "A seismic safety element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.
>
> The seismic safety element shall also include an appraisal of mudslides, landslides and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, groundshaking, ground failure and seismically induced waves."

The Guidelines (California Council on Intergovernmental Relations, 1973) for the preparation of local general plans states that:

> "The intent is that <u>all</u> seismic hazards are to be considered, event though only ground and water effects are given as specific examples. The basic objective is to reduce loss of life, injuries, damage to property, and economic and scoial dislocations resulting from future earthquakes."

Based on the interpretation of the intent of the law, the Guidelines define the scope of the Element as including:

1. A general policy statement.
2. The identification, delineation and evaluation of natural seismic hazards.
3. The consideration of existing structural hazards.
4. An evaluation of disaster planning program.
5. The determination of specific land use standards related to level of hazard and risk.

The Guidelines indicate that the identification of natural seismic hazards should include the following:

"1. General structural geology and geologic history.

2. Location of all active or potentially active faults, with evaluation regarding past displacement and probability of future movement.

3. Evaluation of slope stability, soils subject to liquefaction and differential subsidence.

4. Assessment of potential for the occurrence and severity of damaging ground shaking and amplifying effects of unconsolidated materials.

5. Identification of areas subject to seiches and tsunamis.

6. Maps identifying location of the above characteristics."

The following technical evaluation is intended to meet or exceed these requirements.

B. PHILOSOPHY OF THE ANALYSIS

The quantitative study of the strong shaking of earthquakes is a relatively young science. It was begun in California in the early 1930's, but has been limited by the necessity of having the right instruments in the right place when a significant earthquake does occur. Much information has been acquired over the last 40 years, but there are significant gaps and much remains to be learned.

With this relatively limited level of basic data, two different approaches to the development of a Seismic Safety Element are available. One can utilize broad generalizations to describe expected events; certainly the inadequacies of the data favor this approach. On the other hand, if the results are to be used by engineers in designing safer structures, then a commitment to mathematical form is necessary. To this end, the analysis is developed in this way, whenever possible, and presented in chart or graph form. Qualitative descriptions of the results are included for the lay reader, and a brief discussion of methodology, terminology, and concepts is included in Section C. A Glossary of Terms for reference purposes is included at the back of the report.

The basic philosophy within which this analysis has been developed is that the intent of the Seismic Safety Element is to plan and prepare for the future based on what we know today rather than waiting until we know all that we would like to know.

C. CONCEPTS, METHODOLOGY, AND TERMINOLOGY

1. General Statement

The Seismic Safety Element is probably the most technically-oriented of all the mandated elements of the General Plan. For this reason, and because of the wide range of backgrounds and experience of expected readers, it is appropriate to include in the Introduction a discussion of concepts, methodology, and terminology to be used in developing the technical base for this element. This discussion is intended to supply not only a dictionary function of technical terms and concepts, but, most importantly, to establish the systematic cause and effect relationships between the several seismic hazards, and the need for a systematic analysis of available information.

The topics discussed in the following sections of the introduction are arranged in an order that becomes increasingly more difficult for the layman. Sections 2 through 4 discuss concepts and terms commonly included in newspaper accounts of earthquakes, while later sections discuss the concepts necessary in the technical analysis of earthquake hazards. The latter are intended primarily for readers with engineering or scientific backgrounds, but may also be of interest to the lay reader.

The text of the report is arranged in a similar order. Each section becomes increasingly more complex, and the later sections are intended to document the analysis for engineers and earth scientists who may wish to expand on or apply the data to the detailed analysis of individual sites.

2. Types of Hazards

The several seismic hazards discussed in the C.I.R. Guidelines can be grouped as a cause-and-effect classification that is the basis for the order of their consideration. Earthquakes originate as the shock wave generated by movement along an active fault. The primary natural hazards are ground shaking and the potential for ground rupture along the surface trace of the fault. Secondary natural hazards result from the interaction of ground shaking with existing ground instabilities, and include liquefaction, settlement and landslides. In this context, tsunamis, or "tidal waves", and seiches would be primary natural hazards.

The potentially damaging natural events (hazards) discussed above may interact with man-made structures. If the structure is unable to accommodate the natural event, failure will occur. The potential for such failure is termed a structural hazard, and includes not only the structures themselves, but also the potential for damage or injury that could occur as the result of movement of loose or inadequately restrained objects within, on, or adjacent to, a structure.

3. Active Faults - The Source of Earthquakes

Earth scientists are generally agreed that earthquakes originate as the result of an abrupt break or movement of the rock in the relatively brittle crust of the earth. The earthquake is the effect of the shock waves generated by the break, much the same as sound waves (a noise) are generated by breaking a brittle stick. If the area of the break is small and limited to the deeper part of the crust, the resulting earthquake will be small. However, if the break is large and extends to the surface, then the break can result in a major earthquake.

These breaks in the earth's crust are called faults. In California, faults are extremely common, and vary from the small breaks of an inch or less that can be seen in almost any roadcut, to the larger faults such as the San Andreas on which movement over many millions of years has amounted to hundreds of miles. In addition to the size of faults, their "age" is also important. Many large faults have not moved for millions of years; they are considered "dead" or no longer active. They were probably the source of great earthquakes millions of years ago, but are not considered dangerous today.

Since faults vary as to the likelihood of their being the source of an earthquake, considerable effort has, and is continuing to be, expended by geologists and seismologists to determine and delineate the faults likely to generate significant earthquakes. The C.I.R. Guidelines define an active fault as one that "has moved in recent geologic time and which is likely to move again in the relatively near future. Definitions for planning purposes extend on the order of 10,000 years or more back and 100 years or more forward." In this definition, "has moved" would normally be taken to mean demonstrable movement at the surface.

The State Mining and Geology Board (1973), for purposes of the Alquist-Priolo Geologic Hazards Zone Act (Chapter 7.5, Division 2, Public Resources Code, State of California), "regards faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence as constituting a potential hazard."

The State Geologist (Slosson, 1973, Explanation of Special Studies Zones Maps, p.3 & 4) defines a potentially active fault as one "considered to have been active during Quaternary time (last 3,000,000 years) -- on the basis of evidence of surface displacement." The State Geologist knows the contrast with the State Mining and Geology Board, but also states: "An exception is a Quaternary fault which is determined, from direct evidence, to have become inactive before Holocene time (last 11,000 years)."

The definitions above are compatible if taken in the following sequence:

1. A potentially active fault is one which exhibits evidence of surface displacement during Quaternary time (last 3,000,000 years approximately).

2. A potentially active fault will be considered as an active fault if there is evidence of surface displacement during Holocene time (last 11,000 years, approximately).

3. A potentially active fault will be considered as inactive if, by direct evidence, it can be shown that there has been no displacement during Holocene time.

The key to the practical application of the above definitions is the placement of the burden of proof. The State Geologist will consider a fault as potentially active if there is evidence of surface displacement during Quaternary time. If a fault is so designated as required by the Alquist-Priolo Act, then the burden of proof shifts to the developer to show by "direct evidence" that the fault has not been active (i.e. no surface displacement) during Holocene time. The practical application of this system of evaluation will depend primarily on the interpretation of "direct evidence" in the review and evaluation of the required geologic reports.

The above discussion applies directly to Special Studies Zones as required by the Alquist Priolo Act. To date, no such zones have been established within the study area. However, the State Geologist is required to "continually review zones and to delineate additional zones. In this context, evidence of fault activity in the study area will be discussed herein utilizing the framework of evaluation as provided by the State Geologist and the State Mining and Geology Board. Additional comment on the responsibility for evaluation of geology/seismic hazards is included in Section D of this Introduction, and also as pertinent in that part of the text covering the evaluation of active and potentially active faults.

4. Describing an Earthquake

Several terms are used to describe the location, "size", and effects of an earthquake. A clear understanding of the meaning of these terms and their limitations is essential to an understanding of the results of the investigation.

The location of an earthquake is generally given as the epicenter of the earthquake. This is a point on the earth's surface vertically above the hypocenter or focus of the quake. The latter is the point from which the shock waves first emanate. However, as discussed above, earthquakes originate from faults. These are surfaces, not points, so the hypocenter is only one point on the surface that is the source of the earthquake.

Magnitude describes the size of the earthquake itself. Technically it is defined as the log of the maximum amplitude as recorded on a standard seismograph at 100 kilometers (62 miles) from the epicenter. The most important part of this definition is that it is a log scale; that is, an increase of 1 on the magnitude scale (e.g. magnitude 5.0 to 6.0) represents an increase of 10 in the amplitude of the recorded wave.

Intensity describes the degree of shaking in terms of the damage at a particular location. The scale used today is the Modified Mercalli Scale of 1931, and is composed of 12 categories (I to XII) of damage as described in Table 1. The Roman numerals are used to emphasize that the units in the scale are discrete categories rather than a continuous numerical sequence as is the magnitude scale. It is important to remember that intensity is a very general description of the effects of an earthquake, and depends not only on the size of the quake and the distance to its center, but also on the quality of the construction that has been damaged and the nature of local ground conditions.

5. Occurrence, Recurrence and Risk of Earthquakes

Earthquakes have had in the past a certain occurrence in space and time. These occurrences may or may not set certain patterns that can form the basis for predicting their occurrence in the future. When such occurrences are analyzed in time, certain characteristics may statistically recur at definite intervals. If it can be shown that a particular magnitude earthquake recurs on a fault on the average of once in a certain time interval, then that interval is said to be the recurrence interval for that magnitude. Or, if the interval of time is set (e.g. a 100-year period), then earthquakes of a particular magnitude may recur a certain number of times in the specified period. This number is then the recurrence rate for that magnitude.

In California small earthquakes occur much more often than large earthquakes. Also, there is a fairly definite pattern in that the log (base 10) of the number of events of a particular magnitude that have occurred in the past is approximately proportional to the magnitude of those events. This relationship appears to apply to larger areas such as California and western Nevada, some smaller areas such as the Los Angeles Basin, the Imperial Valley, etc., and to some faults. However, this relationship does not necessarily apply to all faults, and it should be applied to small areas, such as cities or individual sites, with great care.

Recurrence intervals can be used to indicate the risk of an earthquake in much the same way that recurrence is used to describe the risk of flooding (e.g. 100-year flood). There is one important difference, however. Flood is the result of a

TABLE 1. MODIFIED MERCALLI INTENSITY SCALE OF 1931
(from United States Earthquakes)

Intensity	Description of Damage
I	Not felt except by a very few under specially favorable circumstances. (I Rossi-Forel Scale)
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel Scale)
IV	During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V Rossi-Forel Scale)
V	Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerably in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)
VIII	Damage slight in specially designed structures; considerable in ordinary, substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII to IX Rossi-Forel Scale)
IX	Damage considerable in specially designed structures; well-designed, frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX Rossi-Forel Scale)
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale)
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into air.

random combination of meteorological events, whereas current geologic theory indicates that the buildup of the strain released during an earthquake is more likely to be regular. This regularity suggests that prediction, to varying degrees, may be possible depending on the extent of understanding of a particular fault. In some cases this understanding is limited to a statistical regularity in the number and magnitude of earthquakes generated. For others, such as the San Andreas fault, much more is known on which to base an estimate of the risk involved. For others, little more is known other than that there is some degree of hazard involved.

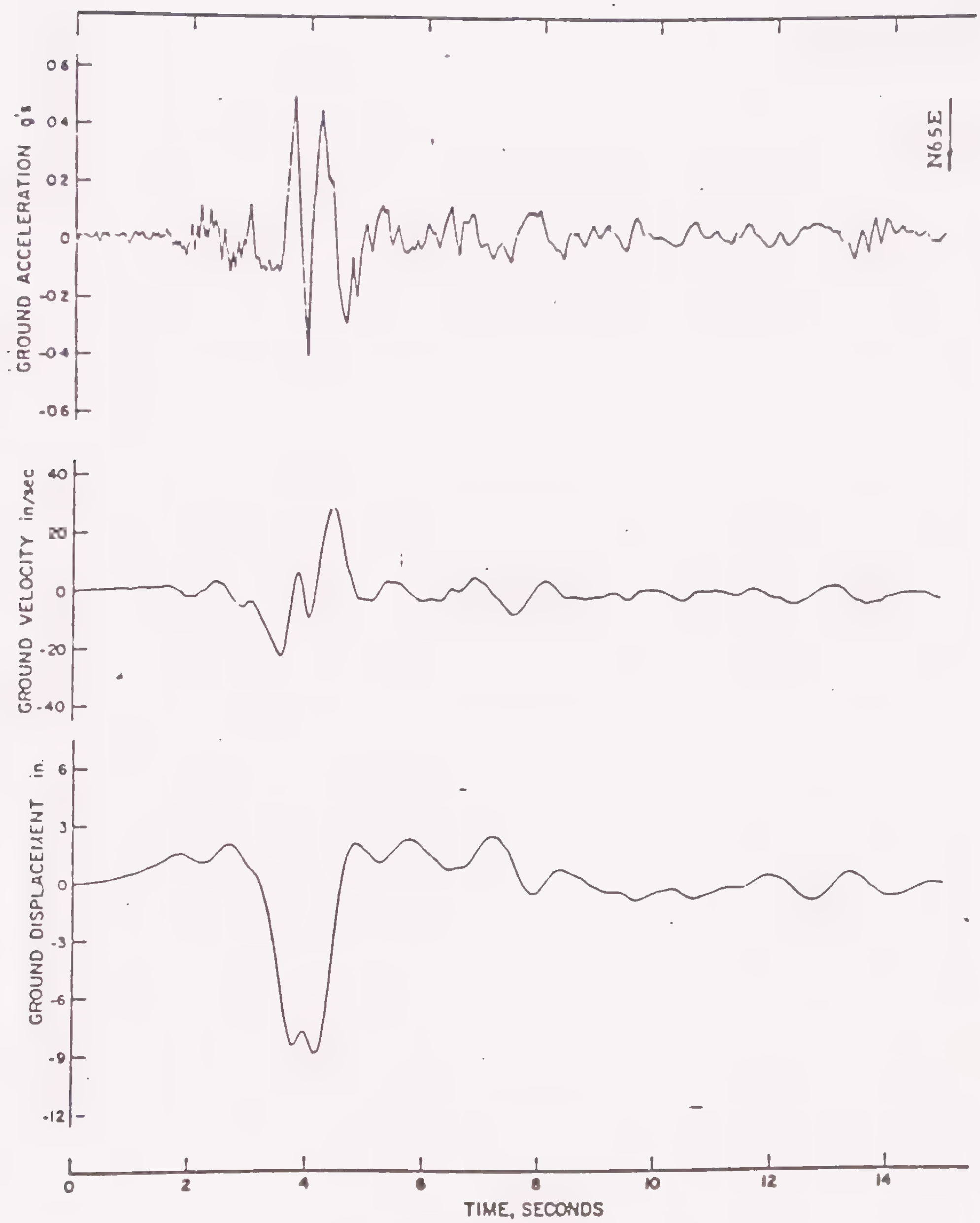
6. Acceleration, Velocity and Displacement

The data of the seismologist and geologist are, in general, not applicable to the engineering design of earthquake-resistant structures. The seismograph, for example, is a very sensitive instrument designed to record earthquakes at great distances. A level of shaking that would be meaningful to an engineer in designing a building would put most seismographs completely off-scale.

As a result, it has been necessary to design and install special instruments to record the strong motions of earthquakes that are of interest to the engineer in the design of earthquake-resistant structures. The first such instruments, principally accelerographs and seismoscopes, were installed by the U.S. Coast and Geodetic Survey in the late 1920's. Since that time, the instrumentation and analytical techniques have been continuously improved, and many excellent records have been obtained of the more recent strong earthquakes.

The following sections are a brief introduction to the concepts, data, and application of strong-motion records. The science is relatively young, and is growing in bursts that follow the recording of a damaging earthquake.

The accelerograph is a short-period instrument (in contrast to the seismograph), and measures the acceleration of the ground or the structure on which it is mounted. Figure 1 shows the ground acceleration recorded just a few hundred feet from the slipped fault during the 1966 Parkfield earthquake. The velocity and displacement curves have been derived from it by integration. It is a particularly good example of the relationships of these three parameters of motion because of the relatively "clean", single-displacement pulse that corresponds to two velocity peaks and four acceleration peaks. Figure 2 shows the more typically complex record of the San Fernando earthquake as recorded at Pacoima Dam. Neither of the two, however, are typical records in terms of accelerations recorded. The Pacoima record shows the largest acceleration recorded to date (1.25g), and the Parkfield record (0.5g) was the largest recorded in the United States before the San Fernando earthquake.



Station 2 N65E Motion.

from Housner & Trifunac, 1967

Figure 1. Ground acceleration, velocity, and displacement. 1966 Parkfield earthquake.

from Housner & Trifunac, 1967.

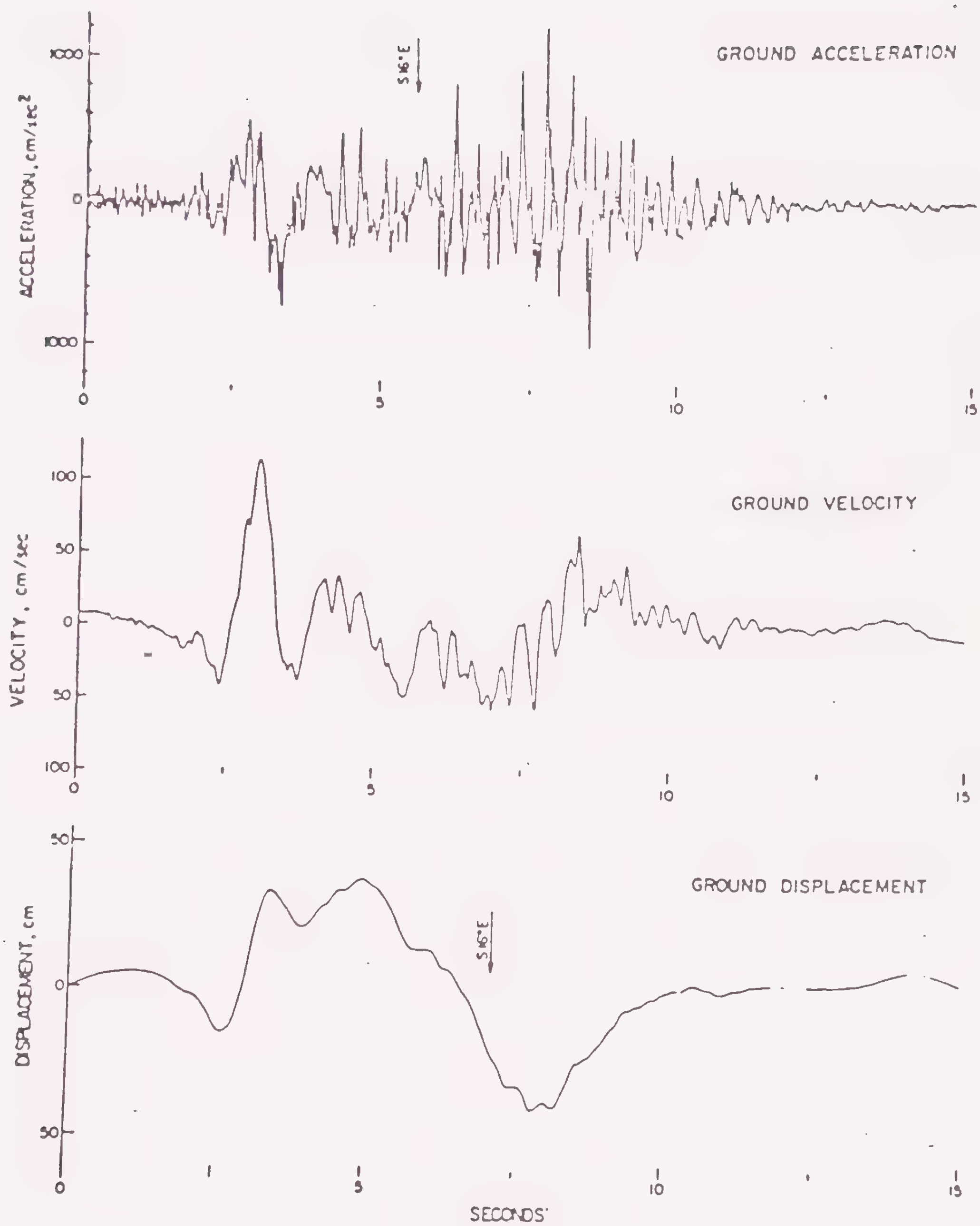


Figure 2. Acceleration, velocity and displacement in the S16°E direction during the main event of the San Fernando earthquake of February 9, 1971, 06:00 (PST).

from Trifunac & Hudson, 1971.

It should also be noted that accelerographs normally record three components; two in the horizontal plane at a right angle to each other, and one vertical. Only one component is shown in each of the two examples.

Maximum acceleration is one of the basic parameters describing ground shaking, and has been the one most often requested by agencies such as FHA in determining the earthquake hazard to residential structures. It is particularly important for "low-rise" construction (up to 3 to 5 stories) and other structures having natural periods in the range of 0.3 - 0.5 seconds or less.

7. Frequency Content - Fourier and Response Spectra

The frequency content of the ground motion is particularly important for the intermediate and higher structures. The problem can be compared to pushing a child in a swing. If the pushes are timed to coincide with the natural period of the swing, then each push makes the swing go higher. However, if the timing is not right, then most of the push is lost "fighting" the natural period of the swing. The situation is similar during earthquakes. Structures have certain natural periods of vibration. If the pulses of the earthquake match the natural period of the structure, even a moderate earthquake can cause damaging movement. However, if the match is poor, the movement and resulting damage will be much less.

Two methods are commonly used to analyze and display the frequency content of an earthquake. A Fourier analysis is a common mathematical method of deriving the significant frequency characteristics of a time-signal such as the record of an earthquake. The results of the analysis are an amplitude term and a phase term. The amplitude is normally plotted against the period for the amplitude to give a Fourier amplitude spectrum for the range of frequencies that are of interest. Since the mathematical procedure is basically an integration of acceleration with time, the Fourier amplitude has the units of velocity.

A response spectrum is derived by a similar mathematical process, but is slightly different in concept. It represents the maximum response of a series of oscillators, having particular periods and damping, when subjected to the shaking of the earthquake. The result is also expressed in units of velocity with the particular nomenclature depending on the precise method used to derive the spectrum.

The Fourier spectrum can be generally described as the energy available to shake structures having various natural frequencies. The response spectrum gives the effect, in maximum velocity, of this available energy on simple structures having various frequencies and damping. At zero damping the two are very similar. Figure 3 shows a plot of both the Fourier spectrum and the response spectrum with zero damping for the Taft earthquake of 1952. Figure 4 shows the response spectrum for the Parkfield record (Figure 1) for several levels of damping.

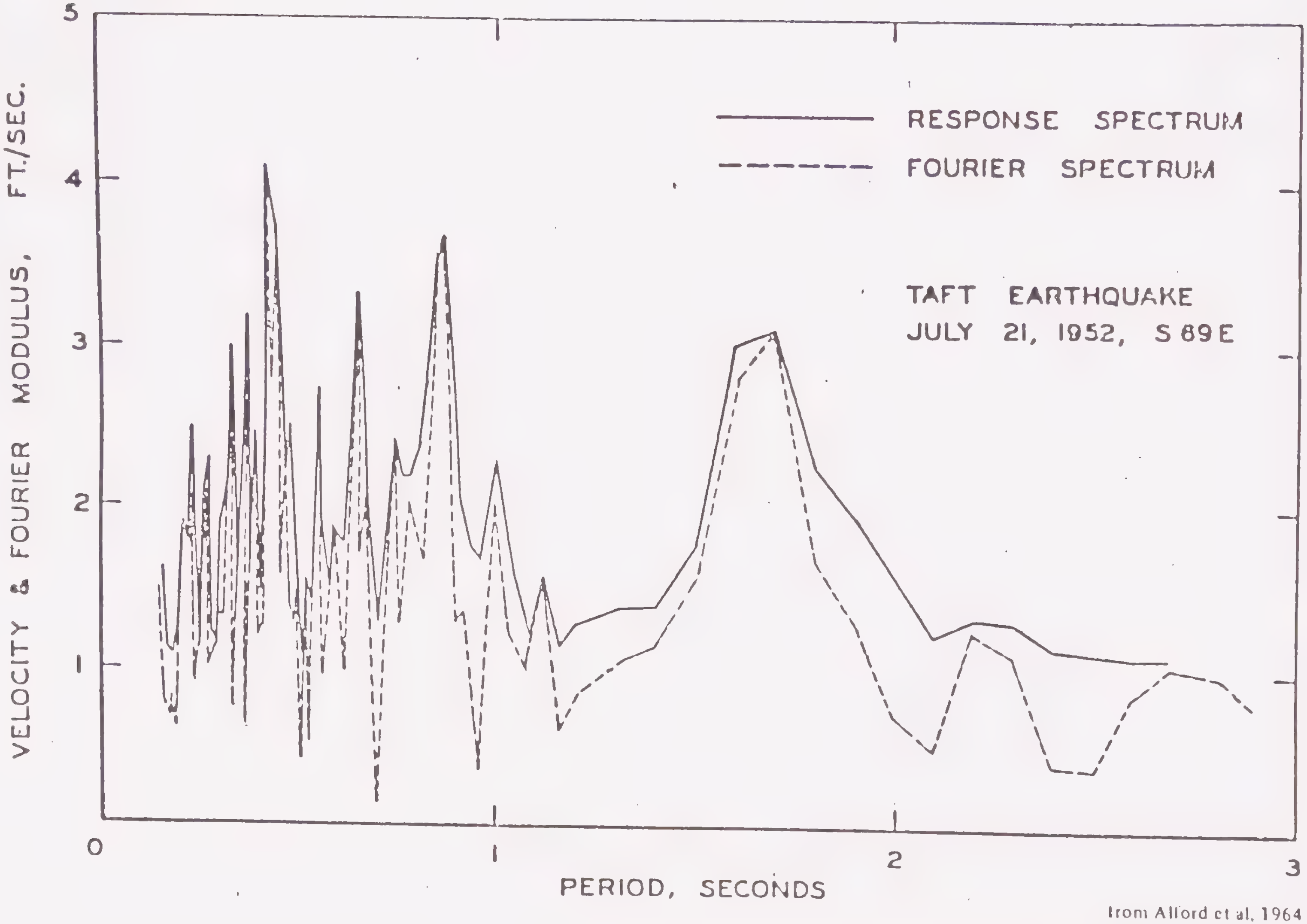


Figure 3. Fourier and response spectra, 1952 Kern County earthquake.

from Alford et al, 1964.

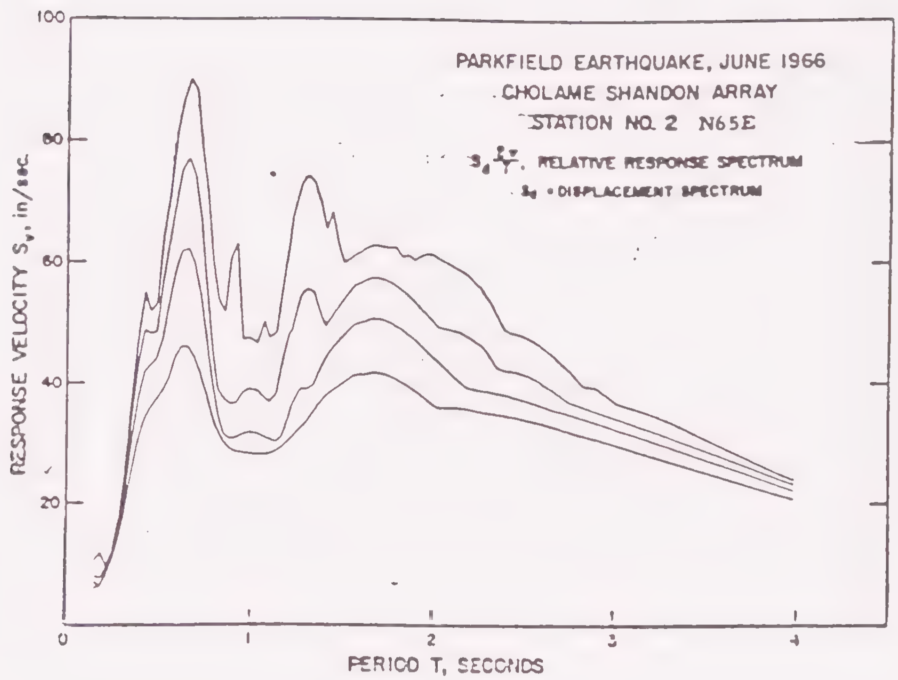


Figure 4. Response spectra, 1966 Parkfield earthquake. The curves are for 0, 2, 5, and 10% damping.

from Housner & Trifunac, 1967.

8. Near-Surface Amplification

The shock waves of an earthquake radiate outward from the source (i.e. the slipped fault) through the deeper and relatively more dense parts of the earth's crust. In this medium, the waves travel at high velocity and with relatively low amplitude. However, as they approach the surface, the velocity of the medium decreases and may become quite variable if layers of different rock types are present. The overall effect is generally an amplification of the wave or of certain frequencies within the spectrum of the wave.

The most consistently applicable effect is the increase in wave amplitude that accompanies the decrease in velocity. This relationship can be compared to laws of mechanics that require the conservation of energy and momentum. In the case of earthquake waves, the energy of velocity is transferred to energy of wave amplitude when the velocity decreases.

A second effect is the amplification of certain frequencies due to the thickness and velocity of near-surface layers of the earth. The geometry of these layers controls the frequency of shaking just like the geometry of a TV antenna controls the frequency it receives best. A striking example is the very high amplification of waves of the 2.5-second period (Figure 5) by the stratification of the old lake beds on which Mexico City has been built. This concentration of the energy in a very narrow frequency range could be disastrous for structures with a matching natural period. Just like the child in the swing, they would move more and more with each successive pulse of the quake. Such pronounced amplifications are unusual, but if present, they can be extremely important.

D. RESPONSIBILITY FOR SEISMIC/GEOLOGIC HAZARD EVALUATION

The responsibility for the evaluation of seismic and geologic hazards lies with both the public and private sectors. The following are suggested as guidelines in determining the distribution of responsibility of the two sectors:

1. The owner or developer of a particular site should be responsible for, and should bear the cost of, the evaluation of those hazards that can be evaluated on or in the near-vicinity of the site.

2. Those hazards that cannot be adequately evaluated at the site should be considered for evaluation with public funds. The nature of the funding may vary depending on the extent of the impact of the hazard.

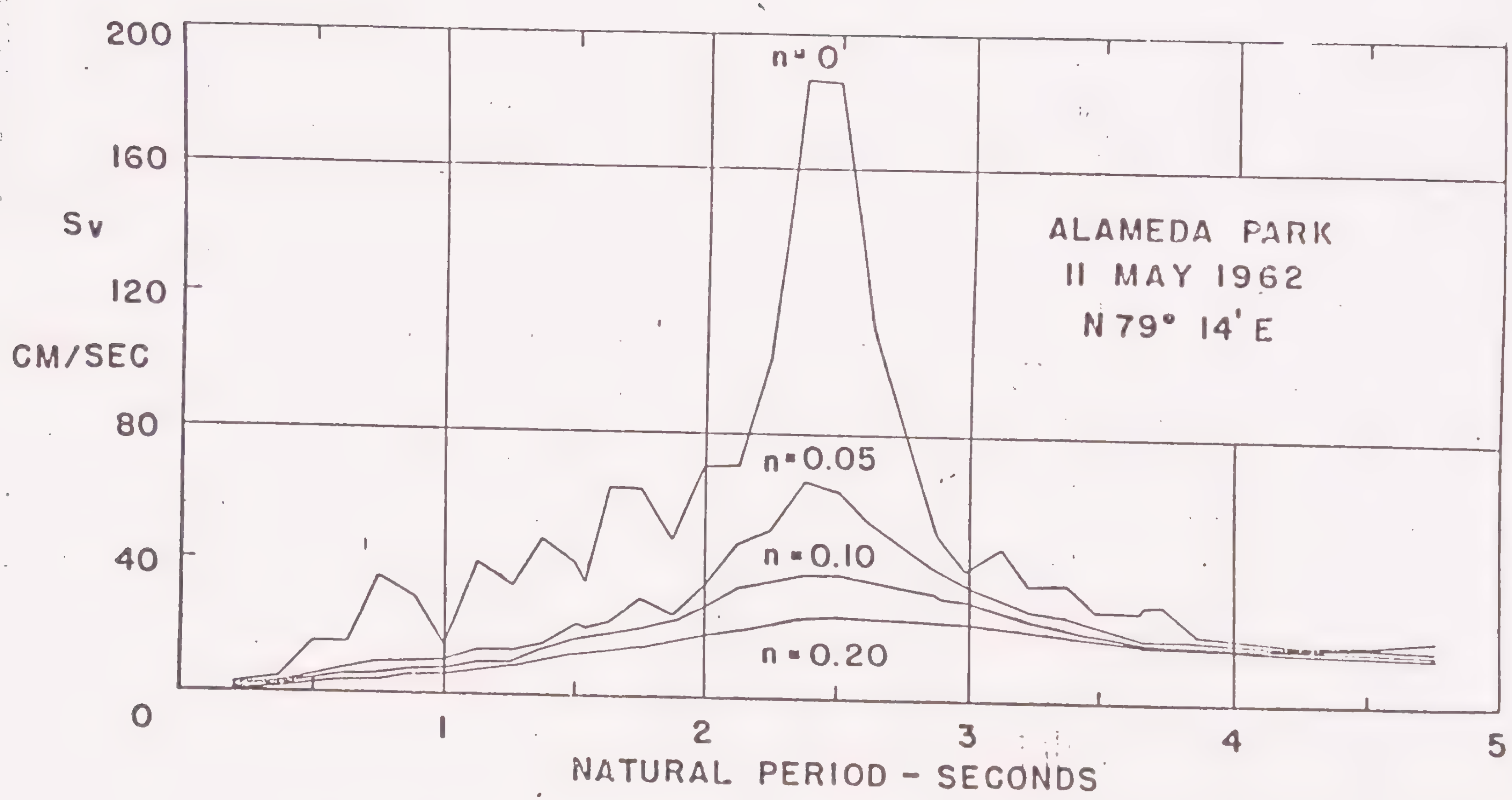


Figure 5. Velocity spectrum, 1962 earthquake near Mexico City.

(See "Mexican Earthquakes of 11 May and 19 May, 1962, *by P.C. Jennings, Earthquake Engineering Research Laboratory, C.I.T.)

3. To facilitate the administration of public safety, it may be desirable to undertake, with public funds, a general evaluation of site-related hazards as they exist within an entire jurisdiction.

The application of these guidelines to geologic/seismic hazards depends on the type of hazard and the availability of information that can be used to evaluate the hazard. For example, faults can be <u>located</u> on a particular site by the engineering geologist during the site investigation. However, the rock formations necessary for <u>evaluation</u> of the activity of the fault are normally present only at certain critical locations, and evaluation of activity may require a publicly funded investigation. On the other hand, landslides can normally be evaluated as part of the site investigation funded by the owner or developer. Public agencies may wish to fund a general investigation of landslide hazards to facilitate the administration of public safety, but the final evaluation must be a part of site evaluation because additional hazard may be introduced by proposed modification of the site.

The distribution of emphasis of this Technical Report is based on these concepts. Those aspects of a particular hazard that cannot be evaluated on a site-basis, or which can more efficiently be evaluated on a regional basis, are emphasized in this analysis. Those hazards that can be effectively evaluated as a part of site investigations are treated in a general way with the intent that the results be used to facilitate the administration of public safety. It should be emphasized that such generalized evaluations should in no way be considered a substitute for a detailed site investigation which must consider not only existing conditions but also any hazards that may result from proposed modifications of the site.

A key step in hazard evaluation is public involvement, through their elected representatives, in the determination of acceptable levels of risk. All hazards involve risk. A technical evaluation may determine certain risk parameters, but only the public can determine the acceptable balance between the risk of a hazard and the cost of mitigation. Because of the extreme importance of this step, primary emphasis is placed on the technical evaluation of available information relating to the risk of seismic hazards. The technical analysis can provide such information, but only the public sector can make the final determination of the acceptability of those risks.

The relationship between the concepts discussed above and the evaluation of specific seismic/geologic hazards is shown in Table 2. The primary responsibility for evaluation of each aspect of a hazard is shown by an "XX", and by an "XXX" if a determination of acceptable risk is involved. Those aspects for which either sector may commonly have a secondary responsibility are indicated by an "X". The intent is to show the distribution of responsibility for evaluation of a hazard; the overall regulatory responsibility of government is not included.

TABLE 2. DISTRIBUTION OF RESPONSIBILITY FOR EVALUATION OF SEISMIC/GEOLOGIC HAZARDS

Hazard	Responsible Sector	
	Public	Private
1. Fault rupture:		
a. Evaluation of fault	XXX	
b. Location at Site		XX
2. Earthquake shaking:		
a. Sources of shaking	XXX	
b. General levels of shaking	XX	X
c. Effects on site		XX
3. Tsunami and seiche:		
a. Risk of occurrence	XXX	
b. Effects on site		XX
4. Dam failure:		
a. Risk of occurrence	XXX	
b. Effects on site		XX
5. Landslide:		
a. Regional evaluation	XX	X
b. Effects on site		XX
6. Liquefaction, settlement, & subsidence		
a. Regional evaluation	XX(1)	
b. Effects on site		XX

X Secondary responsibility
XX Primary responsibility
XXX Primary responsibility including determination of acceptable risk
(1) Evaluation requires determination of expected shaking.

II. ANALYSIS OF SEISMIC HAZARDS

A. GEOLOGIC AND SEISMIC SETTING

The study area, comprising the cities of Azusa, Covina, Industry and West Covina, can be divided into three basic geologic and physiographic units: 1) the San Gabriel Mountains on the north; 2) the San Jose and northern Puente Hills on the south; and 3) the eastern San Gabriel Valley in the central area (Figure 6). By far the largest number of people live in the Valley, but in recent years development has expanded into the geologically more hazardous terrains of the foothills at the edge of the Valley.

The San Gabriel Mountains on the north are composed primarily of relatively hard, igneous and metamorphic rocks that form the steep slopes of the mountain front and San Gabriel Canyon. Tertiary sedimentary rocks (Duarte Conglomerate and Topanga Formation), volcanic rocks (Glendora Volcanics) and Pleistocene alluvial terraces are present locally along the lower slopes of the mountains and at some isolated hills in Azusa.

The San Jose Hills and the northern edge of the Puente Hills are included in the southern part of the study area. They are underlain by sandstone, siltstone and shale of the Puente Formation which are softer and more easily erroded than the igneous and metamorphic rocks of the San Gabriel Mountains.

The eastern San Gabriel Valley is underlain by Holocene (Recent) and Pleistocene alluvium to depths of up to 3,000 feet. The alluvium, or valley fill, is in turn underlain by Tertiary rocks similar to those exposed in the Punete Hills. These units vary considerably in thickness within the area, but the maximum known value is 6300 feet (12,060 feet deep) in the southern part of the area (Sec. 21, T1S, R11W).

The most important faults within the study area are those that form the frontal fault system of the San Gabriel Mountains. This group of faults includes locally the Sierra Madre, Duarte and Lower Duarte faults. Together they comprise the fault system that separates the high mountains on the north from the San Gabriel Valley on the south.

Other faults of importance include the Walnut Creek fault along the north flank of the San Jose Hills, and faults outside the study area including the San Andreas on the north, the Raymond Hill on the west, and the Whittier on the south. These faults and their potential impact on the study area will be discussed in greater detail later in this report.

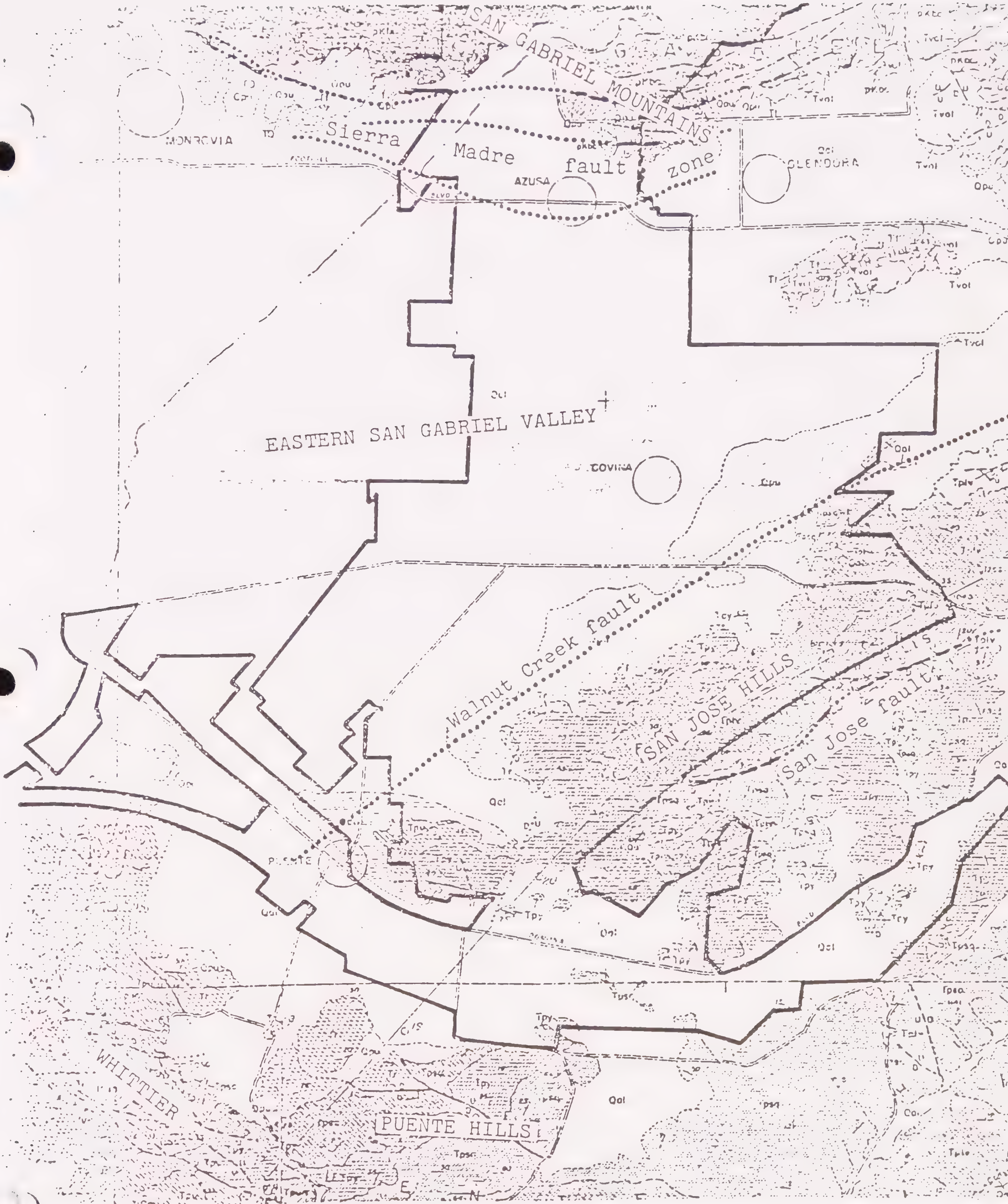


Figure 6. Geologic index map showing location of study area with respect to the San Gabriel Mountains on the north, the San Jose and Puente Hills on the south and the eastern San Gabriel Valley in the central area. Extreme north and west parts of study area not shown. From Schoellhamer et al, 1954

The regional seismicity of the Southern California region and its relationship to the study area is shown on Figures 7 and 8. Figure 7 shows historic fault breaks and the associated earthquakes, and Figure 8 shows all earthquakes of magnitude 6.0 and greater in the region since 1912. The seismicity of the Los Angeles area and its relationship to the study area is shown on Figures 9 and 10. Figure 9 shows earthquake epicenters for the period 1932 through 1949, and Figure 10 shows them for the period 1950 through 1970. Figure 11 shows earthquake epicenters for the study area and vicinity in greater detail, and includes those with magnitudes of less than 4.0. These maps show that there is a clustering of the larger magnitude earthquakes in the area of the Newport-Inglewood fault and along the San Jacinto fault (right edge of Figures 9 and 10), but the smaller earthquakes, particularly magnitude 3 or less, tend to occur as a random "background" with no apparent clustering along any known fault except those noted above. The principal implication that can be drawn from these relationships is that some faults in Southern California show a certain level of earthquake activity or seismicity that can be taken as an indication of their capacity to generate larger earthquakes. Others, such as those mentioned above as being important to the study area, do not have earthquakes clustered along or near them, and their potential for generating damaging earthquakes must be derived from other evidence.

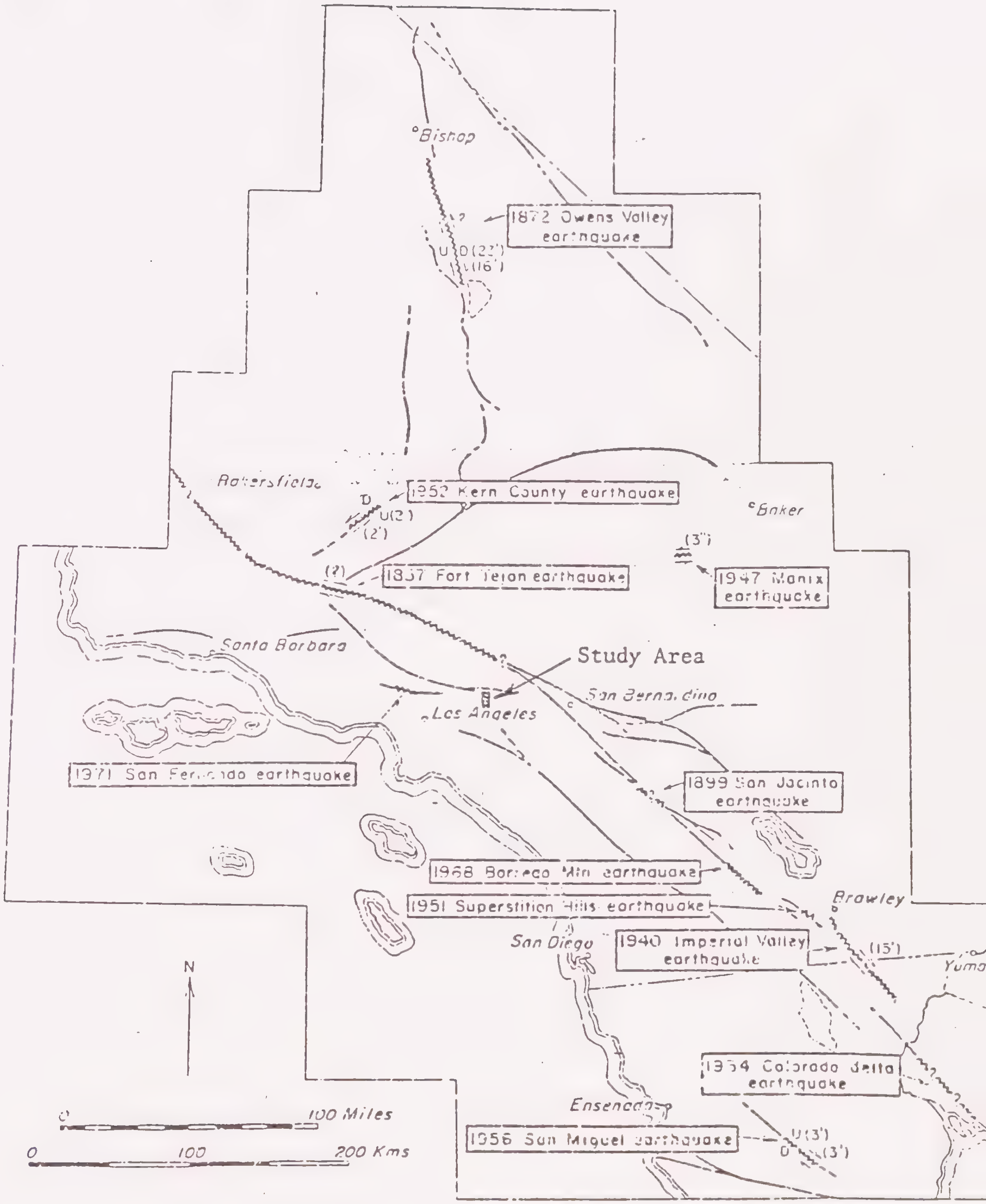


Figure 7. Historic fault breaks and associated earthquakes in the southern California region. From Hileman, Allen and Nordquist, (1973).

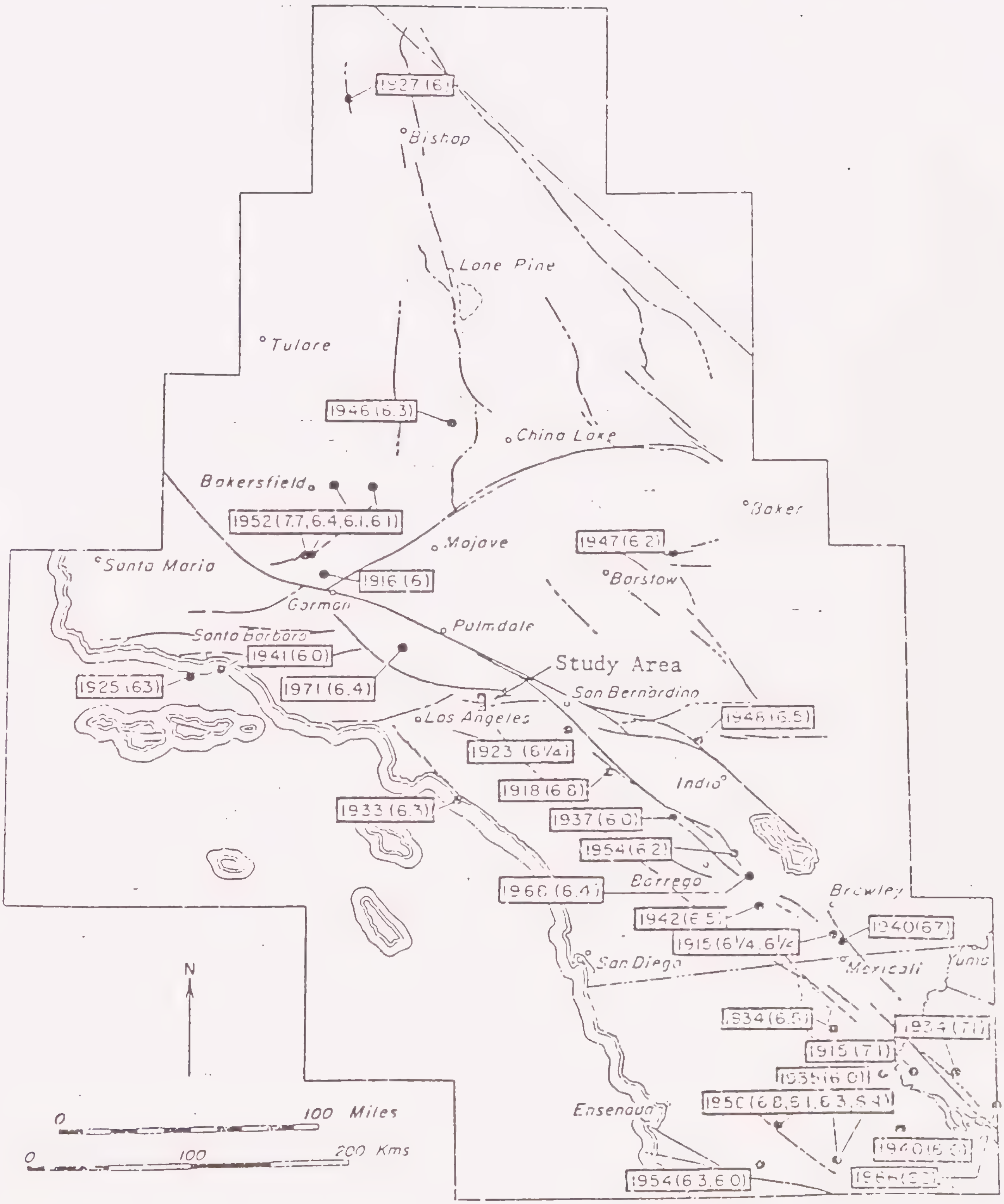


Figure 8. Earthquakes of magnitude 6.0 and greater in the southern California region, 1912-1972. From Hileman, Allen and Nordquist, (1973).

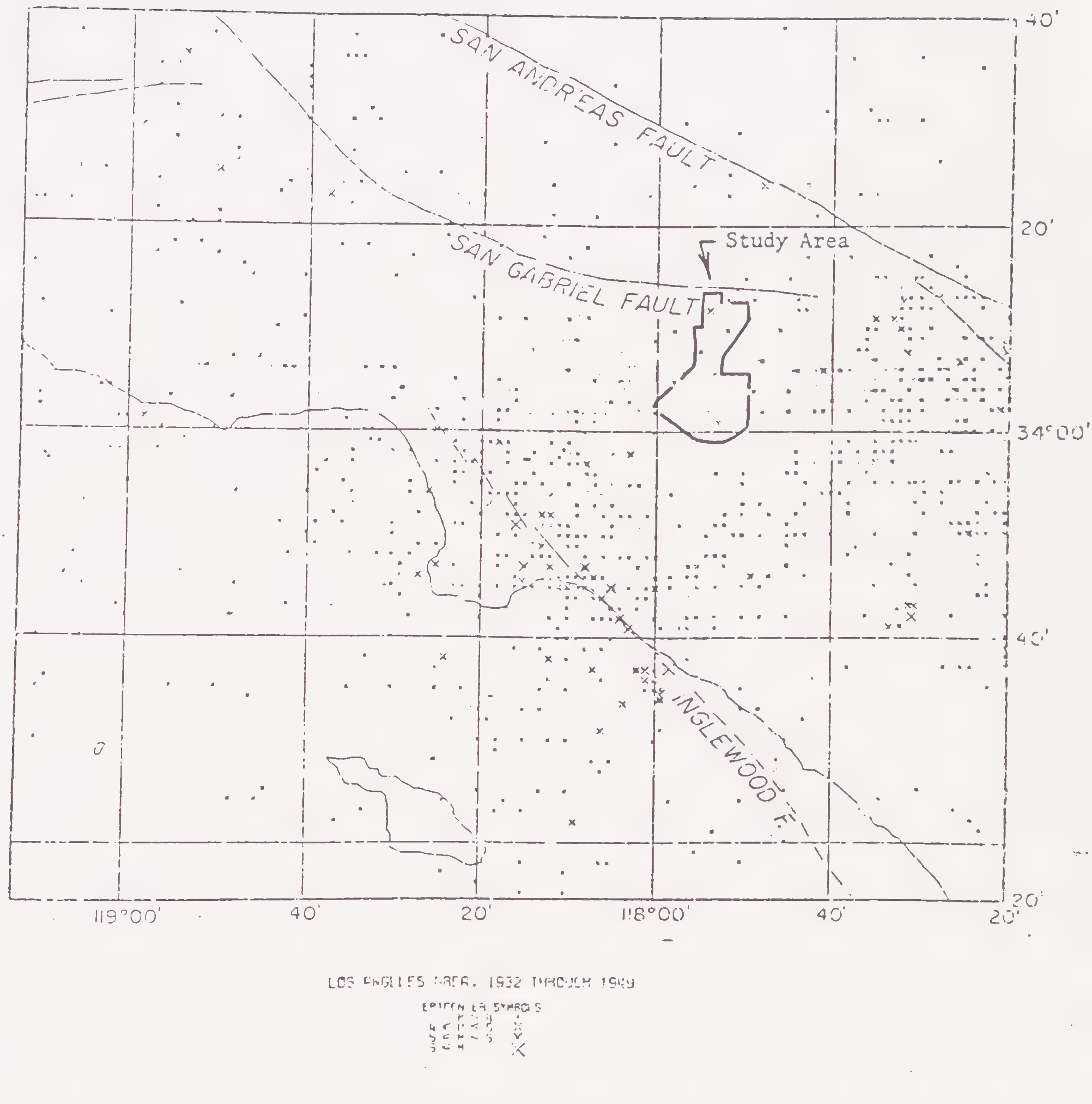


Figure 9. Earthquake epicenters for the Los Angeles area, 1932 through 1949. From Hileman, Allen and Nordquist (1973).

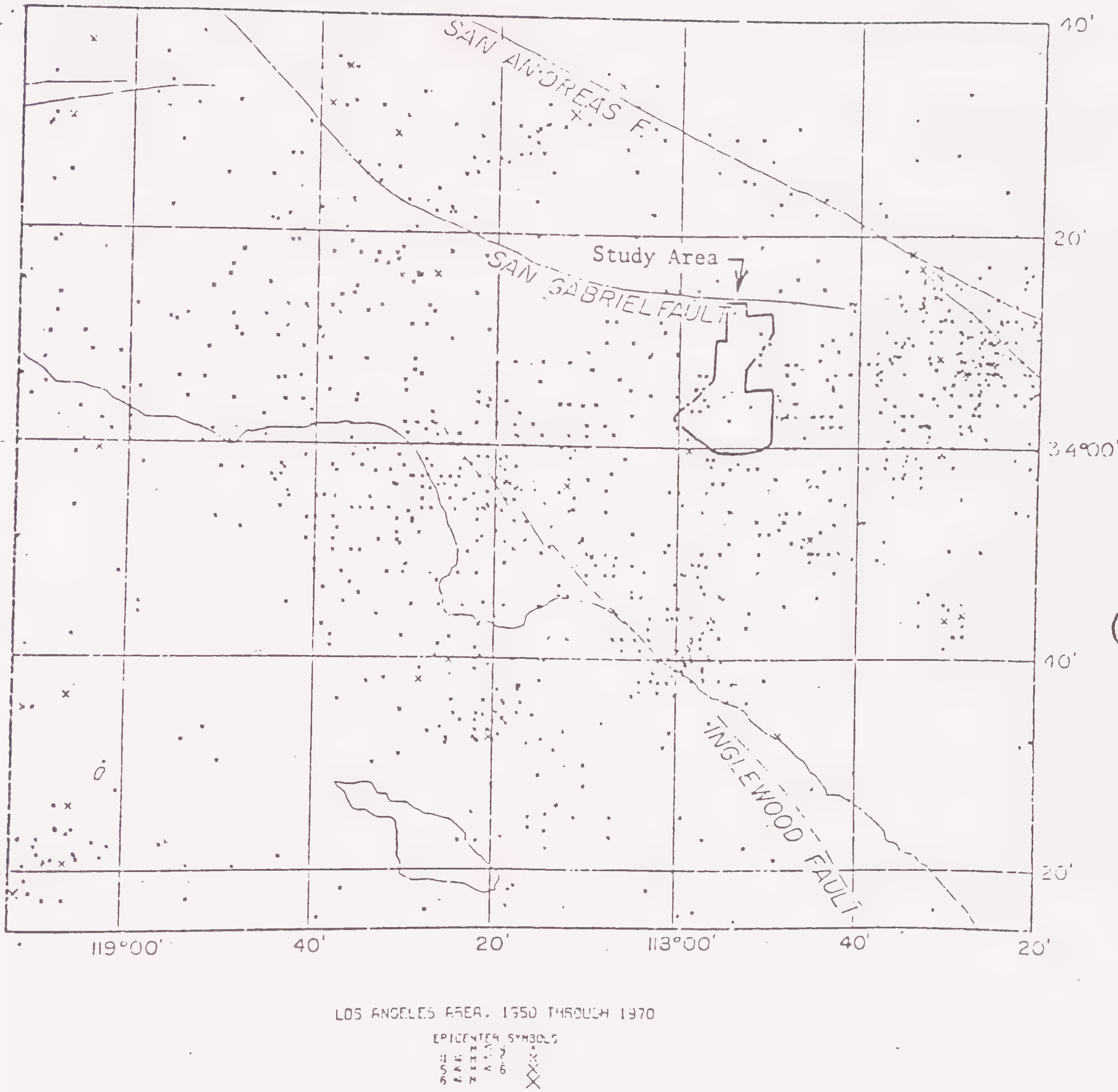
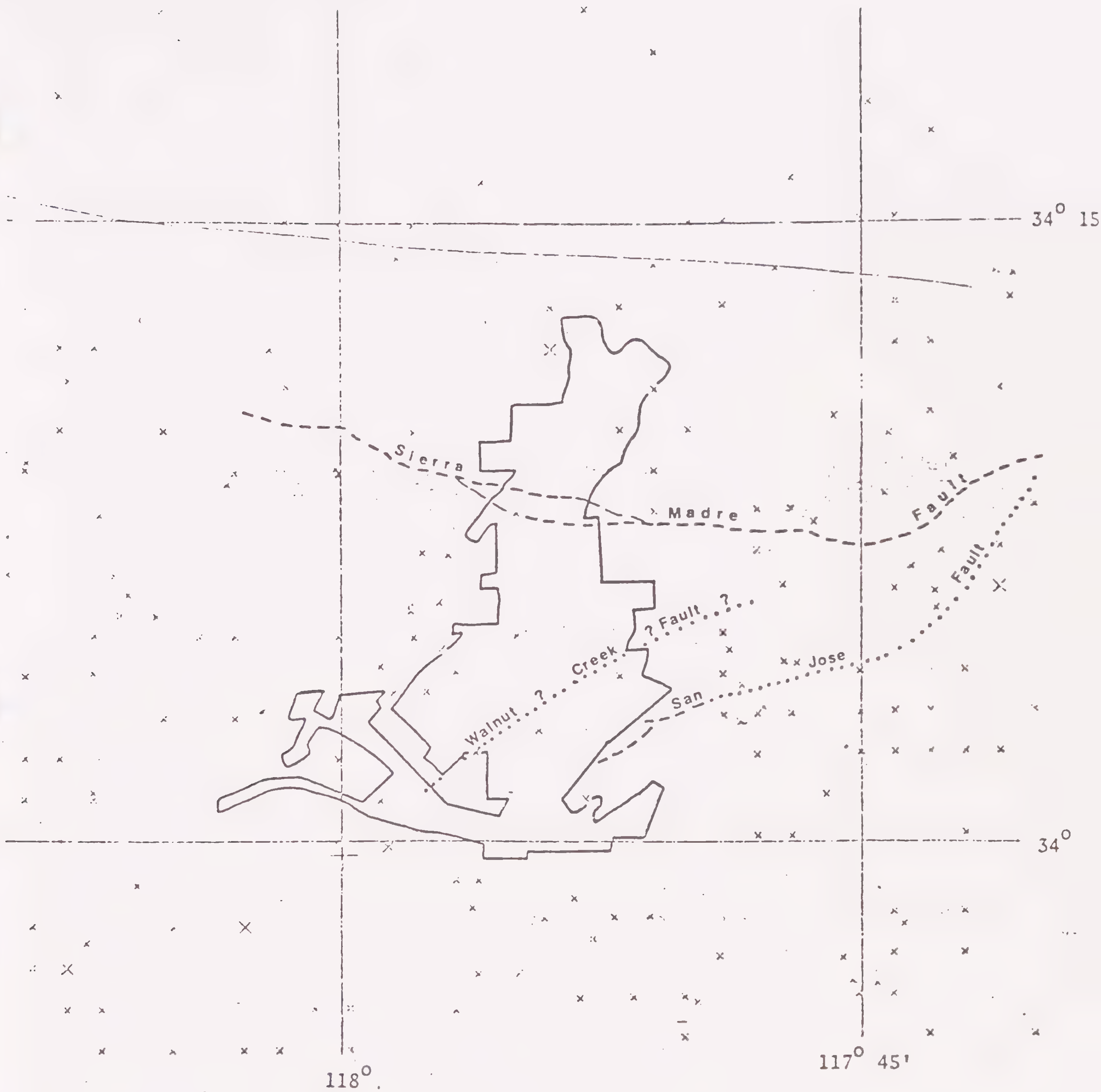


Figure 10. Earthquake epicenters for the Los Angeles area, 1950 through 1970. From Hileman, Allen and Nordquist (1973).



EPICENTER SYMBØLS

$M < 4$	×
$4 \leqslant M < 5$	×
$5 \leqslant M < 6$	×
$6 \leqslant M$	×

Figure 11. Earthquake epicenters for the study area and vicinity for the period 1932 through 1972. Includes all events recorded by Caltech for the period.

B. ACTIVE AND POTENTIALLY ACTIVE FAULTS

1. Methodology

a. General Statement

The assessment of the hazard from an active or potentially active fault involves the determination of two basic parameters that describe the activity of a fault and its capability of generating a damaging earthquake or of rupturing the ground surface. Since definitive data is often inadequate to precisely determine the activity or capability of a fault, the following sections are included to familiarize the reader with the types of data and the geologic judgements involved.

b. Activity of a Fault

The term "active fault" has been used by geologists and geophysicists for many years to describe faults which are known to be the source of earthquakes or which are known to have moved at the surface during historic time. As long as the use of this term was limited to the earth science professions where the limitations of the data are well understood, problems related to a precise definition were minimal. However, the inclusion of the term in legislation at the State level has resulted in an effort by various State agencies and the several professional societies involved to clearly define "active fault".

The definitions of "potentially active fault" by the State Geologist (Slosson, 1973) and "active fault" by the State Mining and Geology Board (1973), discussed in the Introduction, are of considerable help, but the practical aspects of definitive evaluation remain to be established. Also, these definitions relate to activity as determined by, and as applied to, the hazard of fault rupture. Activity as may be suggested by earthquake epicenter locations is not defined, and the relationship between evaluations within the Special Studies Zones and the more general hazard of earthquake shaking is as yet unclear.

While a high degree of conservatism may be feasible in the regulation of construction along active or potentially active faults, the use of the same criteria in establishing codes relating to hazards from earthquake shaking may have profound economic and social impacts.

The activity of a fault is related to recurrence rate which can be derived in at least three different ways:

1. The analysis of the seismicity of a fault may reveal relationships that indicate that, at least statistically, earthquakes of particular magnitudes recur at regular rates. Data suitable for this type of analysis is available for only about the last 40 years.

2. The measurement of the movement of the earth on either side of a fault, or <u>crustal strain</u>, can sometimes be derived from survey data. This information is available for a longer period of time, but movement is often so small it is not detectable from ordinary data. Very accurate surveys have been conducted in recent years, but across only a few faults. If the rate of accumulation of strain is known, then the amount of time necessary to accumulate the strain necessary for an earthquake of a particular magnitude can be estimated from other relationships.

3. The relationship of unique rock units on either side of a fault may yield the <u>geologic slip rate</u> if the ages of the unique units are known. The principal problem with this method is the assumption that rates obtained for a time span of several million, or several tens of millions of years are valid today.

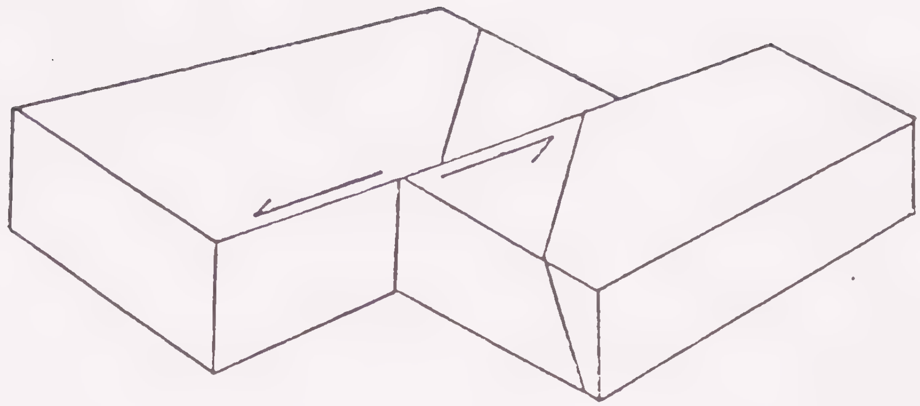
The applicability of any of the above methods depends on the data available.

c. <u>Capability of a Fault</u>

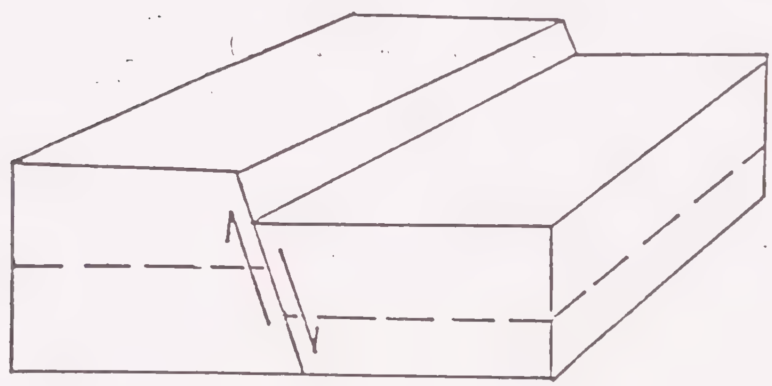
The capability of a fault is defined as the largest earthquake, in Richter magnitude, that the fault will probably generate, if it should move. If a fault has moved during that part of the recent past for which magnitude data are available, the capability of that fault can be estimated from the historic record. However, if the activity of a fault is low, it may not have generated the largest earthquake of which it is capable during that time for which instrumental data are available. The capability of these faults can be estimated from their physical dimensions.

Data on the movements of faults and the magnitudes of the resulting earthquakes have been compiled by Bonilla and Buchanan (1970) from worldwide sources. Their analysis of this data indicates that there are empirical relationships between the length of surface rupture and the magnitude of the resulting earthquake, depending on the type of movement. Simply stated, the longer the fault, the larger the earthquake; but the exact relationship depends also on the type of movement.

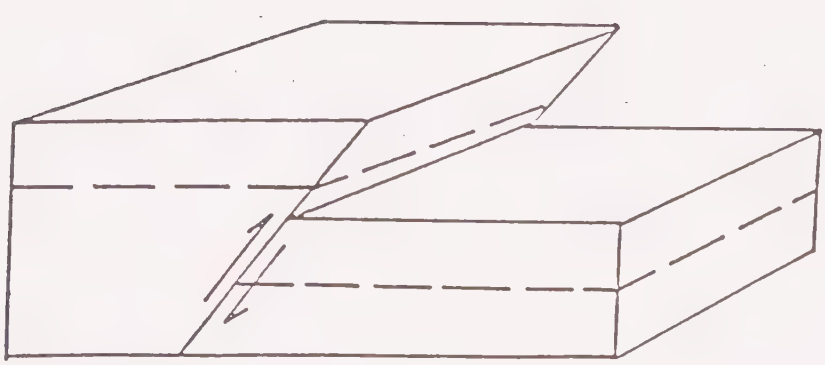
Fault movement can be divided into three basic types illustrated in Figure 12. The type most commonly associated with recent activity is strike-slip movement because it is the dominant movement occurring on the San Andreas fault. It is characterized by horizontal slip of the two adjacent blocks relative to each other, with the dominant direction of movement being parallel to the trend of the fault. The alternative to strike-slip movement is dip-slip, or up-down, movement. Faults of this type, however, should be separated into those that result from a pulling-apart or tensional movement, and those that result from a pushing-together or compressional movement. The former are called normal faults,



Strike-slip or lateral fault



Normal (dip-slip) fault



Reverse (dip-slip) fault

Figure 12. Types of fault movement.

and the latter are called reverse faults.

The relationships between length of rupture and earthquake magnitude for strike-slip and for normal faults are shown on Figure 13. Data is at present inadequate to define a difference in the relationship between normal and reverse faults, but the theory as to the forces involved suggests reverse faults should generate larger magnitudes for comparable lengths of rupture.

The discussion above is for recent fault breaks that can be identified on the ground after the earthquake. The evaluation of a fault's capacity to generate an earthquake, based on data other than earthquakes that it is known to have generated, involves an estimate of the length of the segment expected to move and the type of movement most likely to occur. This requires that the length of the fault be determined, and then that the extent of individual segments of the fault most likely to rupture at one time be determined. This process is very subjective, and depends not only on the interpreter, but also on the detail of knowledge of the fault.

d. Practical Problems in Fault Evaluation

1) Dating a Fault

Dating the most recent movement of a fault is more difficult than is generally believed. The process is essentially one of locating the most recent beds cut by the fault, and the oldest beds that overlie the fault but are not cut by it. If the two sets of beds can be dated, then the time of most recent movement is within the interval between the ages of the two beds. This process is shown diagrammatically in Figure 14.

The process is relatively simple in concept, but may be very difficult if not impossible to apply, depending on conditions. First, the process requires that relatively young beds be preserved overlying the fault; and, second, that they can be dated within the required limits of accuracy. Faults, particularly major faults, are known to exist because they are exposed and can be mapped on the surface. That is, they are not covered along most of their length, but only at isolated localities as along streams or rivers or by terraces along the sea coast. These isolated localities are critical to establishing the minimum time since the last movement on a fault. If these key beds are not present within an area being investigated, it may not be possible to evaluate the activity of the fault from data obtained within that area.

The second problem is dating the beds overlying the fault. "Dating" as applied to nuclear power plant siting requires a determination of the age in years of the beds not cut by the faulting. To do this requires that material suitable for carbon

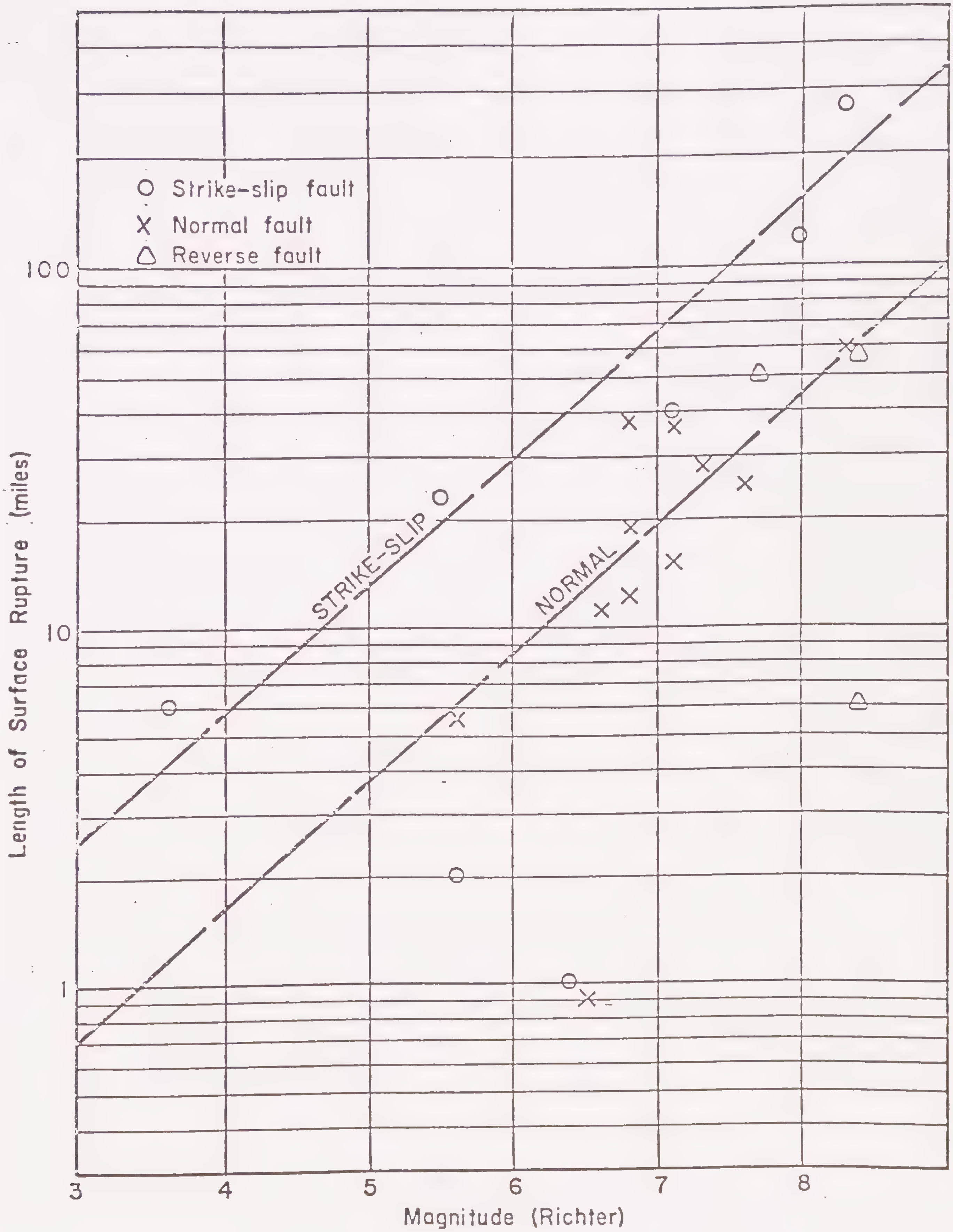
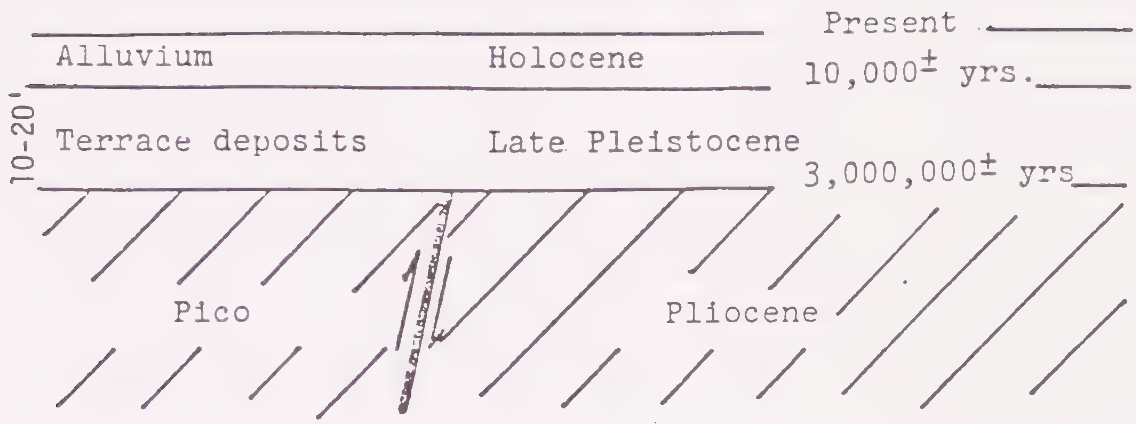
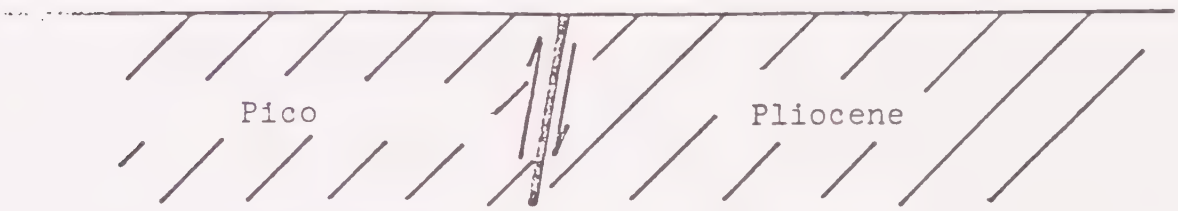


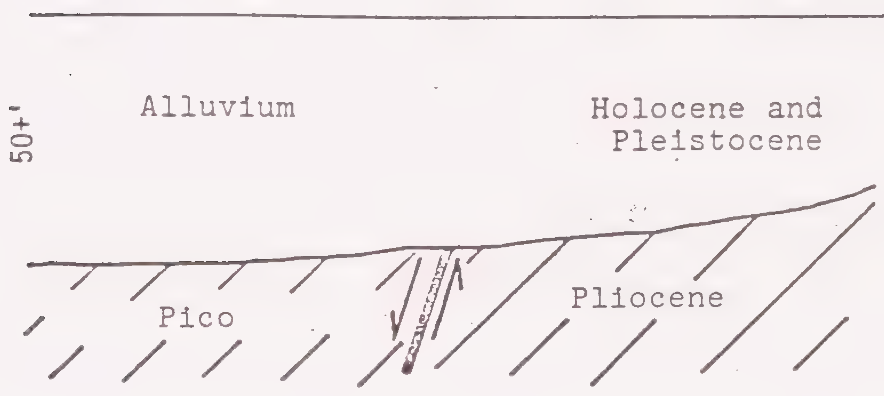
Figure 13. Length of surface rupture vs. magnitude
Data from Bonilla, 1970.



Most recent movement on fault can be dated as post-Pliocene and pre-older alluvium; i.e. between 10,000 and 3,000,000 years ago.



Fault is exposed at surface with no overlying unfaulted beds. Most recent movement cannot be established.



Fault is buried too deep to be exposed in exploratory trench, and cannot be dated unless shallower exposures can be located.

Figure 14. Diagrammatic cross section illustrating conditions related to the dating of a fault.

isotope analysis be recovered from the critical beds or that good correlations be established with beds that have been, or that can be, dated in years. Since the carbon of fossil materials is only rarely preserved in young sediments, dating beds in years may be a very difficult, if not an impossible task, for many faults.

A more practical approach is the dating of faults using the geologic system of age identification. The definition of "active" and "potentially active" faults for purposes of the Alquist-Priolo Act (see Introduction) are phrased using geologic age. Such ages are normally assigned as a part of the geologic mapping and investigation of an area, but the evidence for the age of the younger beds (alluvium, terrace deposits, etc.) is often regional or inferred rather than "direct". Thus, they may not be acceptable as a part of the "direct evidence" for the state of activity of a fault as required by the State Geologist for Special Studies Zones established as required by the Alquist-Priolo Act.

2) Activity Based On Seismicity

The locations of most of the earthquakes (i.e., epicenters) in California are sufficiently close to known active faults to be "assigned" to those faults as their source. However, there are a significant number of earthquakes whose locations cannot be associated with any known fault, much less a fault for which there is other evidence of recent movement. Earthquakes of this type can be considered as a "background" of seismic activity that is composed primarily of smaller quakes (Richter magnitude 4 or less), but which also includes some in the range of 4 to 5.

The problem of separating this "background" of activity from that which should be assigned to particular faults is complicated by inaccuracies in locating earthquake epicenters. As a result, the locations of epicenters, particularly those smaller than magnitude 4.0, may be in error by several miles, and the assignment of most epicenters to a particular fault is subject to considerable question.

A somewhat related problem is the relatively short length of the instrumental record of earthquakes in California. Time periods relevant to fault activity discussed to this point have been of the order of 10,000 to 11,000 years (Holocene time) up to 3,000,000 years (Quaternary time). In contrast, the instrumental record is only about 40 years in length, with qualitative data for larger earthquakes (e.g., the 1857 Fort Tejon earthquake) extending back to the early 1800's. This record can be considered reasonably representative of a 100- or 200-year period, but is certainly inadequate for extrapolations of the order of thousands of years.

e. Summary of Methodology

The potential hazard of a particular fault can be described in terms of its activity and capability. For purposes of comparing faults, activity is described in terms of the recurrence intervals for earthquakes of various magnitudes.

The capability of a fault to generate earthquakes is described in terms of the largest earthquake that it should be expected to generate (i.e., "maximum expectable" earthquake). This determination is based on the length of the fault segment that is likely to move, and, because of the assumptions involved, is rather subjective particularly for faults with low levels of activity.

The activity and the capability of a fault should be considered in that order because the capability may be relatively unimportant if the activity level is low. The minimum level of activity that should be considered as constituting a hazard in any particular area is related to acceptable risk, and is, therefore, a matter of public policy. Also, the minimum level of activity that may be considered hazardous with respect to a fault as a source of earthquake shaking may differ from the minimum level for ground rupture. For these reasons, and because the various jurisdictions involved may wish to establish different levels of acceptable risk, the activity level and capability are discussed for each of the major faults in the study area. However, it should be emphasized that a relatively high capability does not necessarily indicate a high level of hazard. Capability is important if activity exceeds minimum levels of acceptable risk. It is also of importance as an indicator of faults requiring particular attention, but it should not be considered by itself as an indication of hazard.

2. Sierra Madre Fault System

The fault system that bounds the south flank of the San Gabriel Mountains extends from Cajon Pass on the east to at least the San Fernando area on the west. Major fault segments include the Cucamonga, Sierra Madre, San Fernando, and possibly the Santa Susana and San Cayetano faults at the west end of the system. Faults associated with the Sierra Madre within or near the study area, and included here within the overall system of faulting, include the Duarte and Lower Duarte faults on the east and numerous unnamed segments along the extent of the Sierra Madre fault zone.

The primary evidence for the recent activity of this fault system is the 1971 San Fernando earthquake. This magnitude 6.4 earthquake occurred as the result of the upward (thrust) movement of the mountains by about 5 feet along a length of approximately 10 miles between Sylmar and Big Tujunga Canyon. It established that this fault zone is active, and the source of potentially damaging earthquakes.

Additional evidence for recency of movement are faulted Holocene (Recent) alluvial gravels in the Arroyo Seco and older alluvium at several other locations, scarps on the fans near Cucamonga (Eckis, 1928), and the presence of fossil soil containing small roots underlying the thrust fault some 700 feet into the front of the range exposed during the excavation of the Glendora Tunnel (Proctor et al, 1970). This tunnel is 6.2 miles long, extending from San Dimas Wash to Morris Dam, and was built by the Metropolitan Water District in 1968. The following description is excerpted from Proctor, Payne and Kalin (1970).

The sequence, thickness and lithology of the Sierra Madre (Cucamonga) fault zone are as follows: At a distance of 700 feet north of the base of the hills, and 370 feet below the surface, Upper Miocene Puente Formation shale and gouge rest directly on terrace conglomerate and on fossil soil. The gouge is blue and yellow, soft, moist, and is up to 9 feet thick, but also is entirely absent at some places where the shale is in contact with the terrace deposits. Overlying the gouge is 70 feet of oil-stained, crudly bedded shale breccia, followed by 110 feet of intermixed shale, granite and gneiss breccia; and finally 60 feet of chaotic shale breccia containing diorite fragments. The true thickness of the fault zone is about 140 feet. The fault plane varies in its inclination, but the average dip is approximately 11 degrees north.

The best exposure of the Sierra Madre fault is in Arcadia's Wilderness Park, on the west side of the canyon wall just upstream of the bridge that crosses Santa Anita Wash. Here crystalline basement rocks (gneiss) have been thrust over alluvial stream gravels. The fault plane slants down toward the north under the mountains at about 35 degrees.

Another good exposure of the Sierra Madre fault was made in 1971 at Caltech's Jet Propulsion Laboratory in Pasadena. Payne and Wilson (1973) have described the exposures as follows: "Converse, Davis and Associates performed a foundation investigation for the vehicular bridge crossing the channel. A branch of the Sierra Madre fault was discovered in the basement rock thrust over recent alluvium. Dip-slip movement of 0.8 foot was present in the most recent alluvium. A minimum of 185 feet of similar movement within Quaternary materials was deduced after a rotary boring was drilled some 25 feet north of the fault trace. The fault can be seen in the road-cut on the east side of the channel approximately 3500 feet north of the gate, and across the channel within the facility in the cut north of Explorer Road between Buildings 176 and 98. Additional rotary holes were drilled within JPL and several faults were encountered, the traces of which were projected through the facility."

Information bearing on the Duarte and Lower Duarte faults is not as complete as for the Sierra Madre fault proper, but they apparently offset Holocene river gravels with a resulting 200 foot groundwater anomaly. They are, therefore, considered active along with the main trace of the Sierra Madre fault. Information is at this time not adequate to establish which branches are the most recently active, but this fault system (Sierra Madre-Santa Susana-Cucamonga) is included in the list (Hart, 1974; Table 4) of faults to be zoned for special studies under the Alquist-Priolo Act during the Phase II (1974-1975) program (see Appendix B).

Recurrence intervals for the Sierra Madre fault system are difficult to establish. There is no continuing seismic activity that can definitely be assigned to the fault other than the San Fernando earthquake and its many aftershocks, and no long-term measurements of crustal strain have been made. The evidence which does exist is primarily the amount of offset of late Pleistocene or early Holocene (Recent) features such as the scarps on the Dry Canyon fan near Cucamonga and the offset of the faulted gravels in the Glendora Tunnel.

Based on this type of information, Lamar, Merifield and Proctor (1973) have estimated the recurrence intervals at a point on the fault as follows:

Earthquake Magnitude	Point Recurrence (Years)
6	100
7	300
8	800

These values are compatible with the 200-year age dating of a wood fragment taken from material involved in an older San Fernando earthquake (Bonilla, 1973).

Of the above values, Lamar, Merifield and Proctor consider the magnitude 6 or 7 events as the most probable or most likely to occur. The Division of Mines and Geology (Greenfelder, 1974) assigns a magnitude of 6.5 as the maximum probable earthquake for each of the major segments of this fault. Since the 1971 San Fernando earthquake was magnitude 6.4, it is reasonable that the maximum probable, or maximum expected, earthquake is approximately magnitude 6.5.

Dr. Clarence Allen of the California Institute of Technology suggests (in Lamar, et al, 1973) that the maximum credible earthquake, which could occur somewhere along Sierra Madre system, could have a magnitude of 7.5, and a recurrence interval of about 200 years. This recurrence interval is for the entire Sierra Madre system. The magnitude 7.5 event can be expected about every 600 years on the Sierra Madre segment of the fault system, if nine feet of movement (Lamar, Merifield, and Proctor, 1973) is assumed for each event. The maximum credible earthquake is normally applied to structures such as atomic power plants, but is not normally a design consideration for normal uses or critical uses such as hospitals or schools.

3. Whittier Fault

The Whittier fault is the northwestern segment of the Whittier-Elsinore fault zone that extends from near the Mexican border (Laguna Salada segment) to just north of the City of Whittier (Jennings, 1973). Jennings' map shows the faults as having Quaternary displacement (during last 2 million years), but without historic (last 200 ± years) movement. Ziony, Wentworth, Buchanan-Banks and Wagner (1974) show the fault as being active in the Pleistocene (at least 11,000 years ago) but not the Holocene.

Greensfelder (1974), on his map of Maximum Expected Bedrock Accelerations from Earthquakes in California, shows the Whittier-Elsinore fault as "active or potentially active" and as the potential source of a magnitude 7.5 earthquake. Lamar, Merifield and Proctor (1973) estimate recurrence intervals for this fault zone as follows:

Earthquake Magnitude	Point Recurrence Interval (Years)
6	300
7	2000
8	6000

However, they emphasize that this estimate is based on geologic slip averaged over the last 6 million years (4.8 km/6,000,000 years = 0.08 cm/yr), and that there is no seismic or strain evidence to substantiate rates of movement or the size earthquake to be expected. It should also be noted that much larger offsets (32 km) are postulated for the middle Miocene suggesting that movement may be decellerating, and that rates derived from averaging over long periods of geologic time may not be applicable to the present.

For purposes of this report, the Whittier fault is considered active and the potential source of a moderate earthquake. The magnitude 7.5 earthquake of Greensfelder (1974) is considered the "maximum credible" event, and the magnitude 6.0 event of Lamar, Merifield and Proctor (1973) is considered the "maximum probable" or "maximum expectable" earthquake.

4. <u>San Andreas Fault</u>

The San Andreas fault zone has been divided by Allen (1968) into several areas of contrasting behavior (Figure 15). The area of particular interest is the segment between San Bernardino and Parkfield that generated the Fort Tejon earthquake of 1856. This was one of the three "great earthquakes" of California's historic record, and this segement of the fault has not moved since. It is the closest part of the fault to the area and is generally considered as the segment capable of generating the largest earthquake.

The segments of the fault to the northwest and southeast of the 1857 break are "active areas" that experience earthquakes of medium to small magnitude on a fairly regular basis. The 1857 break, however, is not moving, but is storing energy. The approximate range of this storage can be deduced from the movements at either end. Pertinent data, summarized in Table 3 indicate that movement in the northwest is occurring at a rate of 5-6 cm/yr while that in the southwest is approximately 8.5 cm/yr. Current theory suggests that the differential between the two rates is being taken up in the Transverse Ranges near the south end of the segment, and that a rate of approximately 5-6 cm/yr is applicable to most of the segment of the 1857 break. This rate is compatible with other considerations (Brune et al, 1969) relating to movement on the fault.

TABLE 3
STRAIN ACCUMULATION AND FAULT SLIP
CENTRAL AND SOUTHERN SAN ANDREAS FAULT

(From Greensfelder, 1972)

Area and Triangulation Net	Strain Accumulation and Fault Slip
1. Central California Active Area:	
a. San Francisco Bay Area, 1906 - 1969	5 - 6 cm/yr displacement between Mt. Diablo and San Francisco Penninsula; both strain and fault slip.
b. Salinas River, 1944 - 1963	3 cm/yr slip on San Andreas fault.
2. Area of 1857 Break:	
a. San Luis Obispo to Avenal, 1932 - 1951	1.5 cm/yr slip and strain.
b. Gorman, 1935 - 1956; Palmdale, 1938 - 1958; Cajon Pass, 1949 - 1963; Newport Beach to Riverside, 1929 - 1953	No significant movement detected.
3. Southern California Active Area:	
a. Imperial Valley, 1941 - 1967	8.5 cm/yr regional displacement.

See Figure 15 for location of areas.

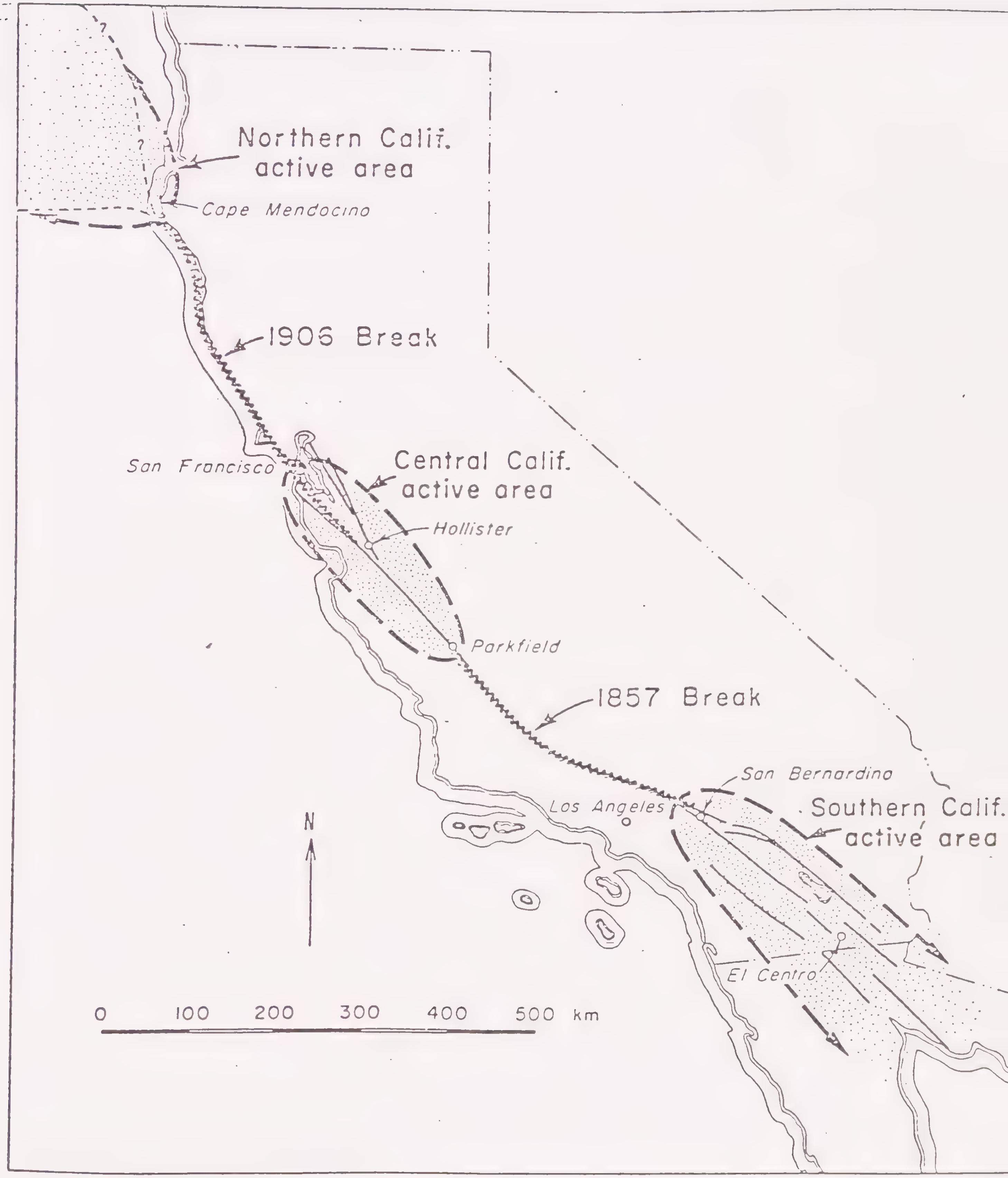


Figure 15. Areas of contrasting seismic behavior along the San Andreas fault zone in California.

(From Allen, 1968, p. 72)

The magnitude of the earthquake generated by slip on a fault is approximately proportional to the logarithm (base 10) of the movement (surface displacement) that occurs. Data on displacement and magnitude compiled by Bonilla (1970) for the San Andreas and faults of similar movement are listed in Table 4 and are plotted on Figure 16. The fitting of a straightline curve to the data is somewhat arbitrary, and in this process the values for the San Andreas itself are given more weight.

Table 4
FAULT DISPLACEMENT AND EARTHQUAKE MAGNITUDE
STRIKE-SLIP FAULTS IN CALIFORNIA

	Fault	Year	Fault Displacement (feet)	Earthquake Magnitude (Richter)
1.	San Andreas	1906	20	8.3
2.	Imperial	1940	19	7.1
3.	Mannix	1947	0.25	6.4
4.	Imperial	1966	0.05	3.6
5.	San Andreas	1966	0.6	5.5

Magnitude and displacement (Figure 16) can be combined with a rate of displacement to give recurrence intervals for various magnitudes. Figure 17 shows this relationship for four rates of displacement. The most important consideration is that 118 years have passed since this segment last moved. Regardless of the rate of displacement assumed, there is probably enough energy stored in this segment of the San Andreas fault to generate a major earthquake at any time. If a 6 cm/yr rate is valid, the energy stored already is sufficient to generate an earthquake of a magnitude of approximately 8.3. This is the estimated magnitude of the great San Francisco earthquake of 1906.

The reasoning developed in the paragraphs above is not new to most geologists, seismologists, and earthquake engineers. It is the reason one hears from time-to-time about the prediction of a "great earthquake" on the San Andreas fault near Los Angeles. From a scientific standpoint, such an earthquake must be imminent. The question is not "if", it is "when", and the longer it waits, the larger it will probably be.

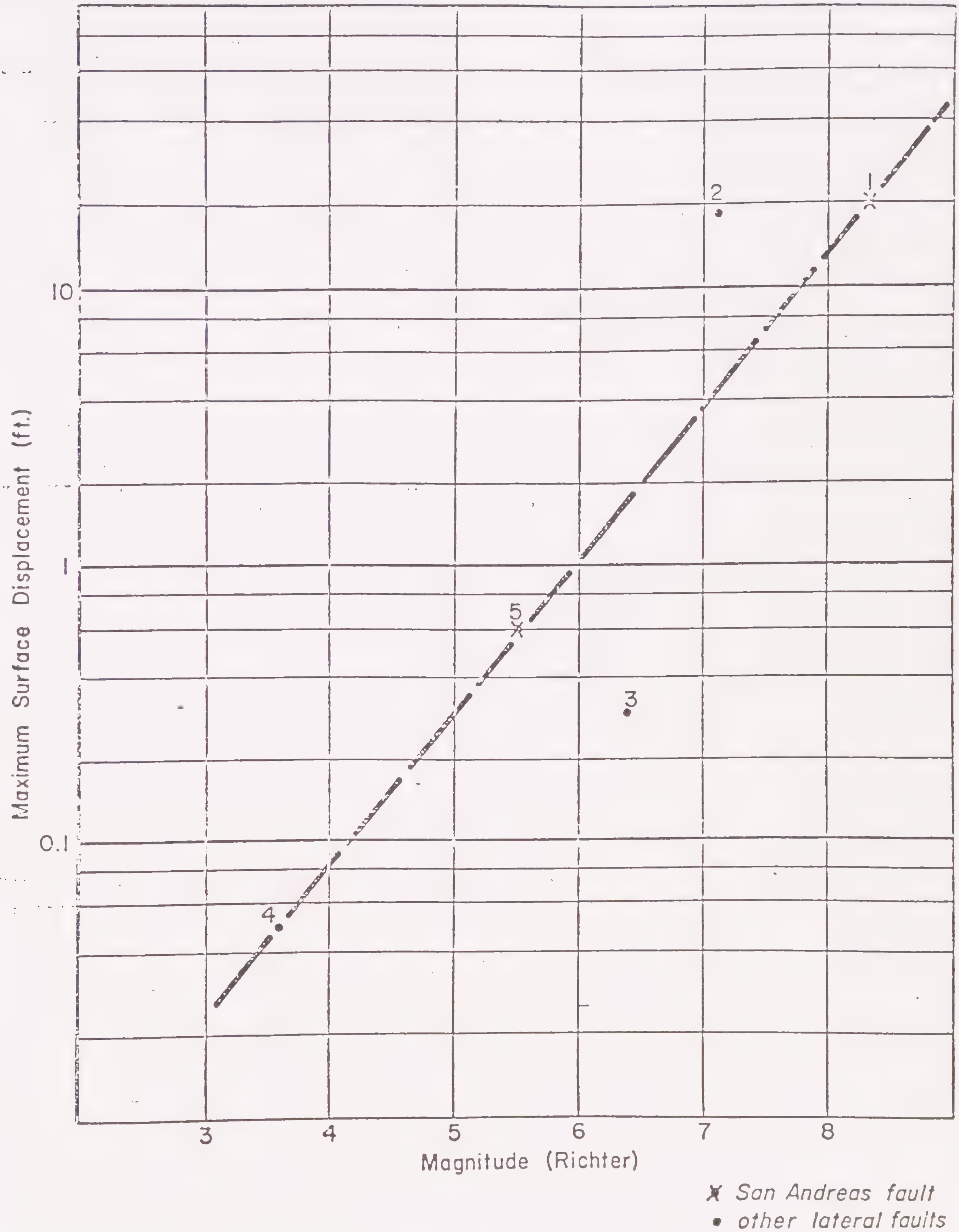


Figure 16. Earthquake magnitude vs. surface displacement for strike-slip faults. Data from Bonila, 1970.

Figure 17. Recurrence vs. earthquake magnitude, San Andreas fault.

For purposes of further analysis in later sections of this report, the magnitude of the expected earthquake is taken at 8.5. No specific recurrence interval is required for risk evaluation, as the event appears certain to occur sometime within the next 100-year period.

5. Walnut Creek Fault

The existence of the Walnut Creek Fault is based on a groundwater barrier postulated by the California Department of Water Resources (1966) as being present along the north flank of the San Jose Hills within the city limits of Covina and West Covina. However, Los Angeles County Flood Control District maps (1969 and 1973) do not show a groundwater barrier, as the contours on the water table can be drawn just as realistically without a barrier. Since there is no surface evidence for the fault and the subsurface evidence is questionable, this fault is not considered further in this analysis.

6. San Jose Fault

The San Jose Fault forms a prominent groundwater barrier in the Claremont area, and is exposed at the interchange of the 210 and San Bernardino Freeways. At this location granite has been thrust south over Miocene sedimentary and volcanic rocks. Its trace westward is defined by topographic saddles, and the Puente Formation becomes overturned along it at Mt. San Antonio Jr. College. The fault has not been mapped to extend into the city limits of West Covina. Its overall length is about 15 miles. There is no surface expression of this fault on the alluvium.

7. Raymond Hill Fault

The Raymond Hill fault is located to the west of the study area and is probably active. It does not present a ground-rupture hazard to the cities involved in this study. It is unlikely that it would generate an earthquake of greater magnitude than those expected on the nearby Sierra Madre fault, and consideration of the latter in the ground-shaking analysis should equal or exceed the expected shaking from the Raymond Hill fault.

8. Workman Hill Fault Extension

A northwestward trending buried extension of the Workman Hill fault has been suggested by oil well records (Calif. Dept. Water Resources, 1966). The fault can be seen in the hills east of Whittier Narrows Dam and its extension would lie under the cities of Industry, Rosemead, and San Gabriel. Its location is based on a 3000-foot difference in depth to basement rock between two oil wells south of the San Bernardino Freeway. The basement could be folded here to explain the difference in depth (Kingsley, 1963), but a fault explanation is more probable. The Quaternary sediments apparently are not affected because there is no groundwater barrier in this area; and this fault is, therefore, not considered active.

9. Summary of Faulting

Of those faults located within the study area, only the Sierra Madre fault zone and its major branches, the Duarte and Lower Duarte fault, are considered active and a significant hazard with respect to ground rupture. These faults are included in the Phase II program of the Division of Mines and Geology in implementing the Alquist-Priolo Act, and the State Geologist will probably establish a Special Studies Zone or Zones along these faults sometime in 1975. Documents distributed to date by the Division of Mines and Geology relevant to this act are included as Appendix B of this report.

Active faults located within the study area or sufficiently close to be the source of potentially damaging earthquake shaking include the Sierra Madre fault in the northern part of the study area, the Whittier fault south of the area, and the San Andreas fault to the north. Recurrence intervals for earthquakes expected on these faults are summarized in the next section.

C. RISK

The analysis of events to be expected from the several faults in the study area has defined these events in terms of a magnitude and a recurrence interval. The level of risk associated with each event is indicated by the recurrence interval in much the same manner as the risk from other natural hazards, such as flooding, is defined by a recurrence interval. For example, it is common practice to design flood-prevention works to accommodate the flows from a 100-year storm. Where a higher level of protection is desired, as for example along the Los Angeles River, the design levels are increased to accommodate the flows from storms occurring at roughly 300-500 year intervals.

The risk of earthquake should be considered in a similar manner. Design for the 100-year event is considered minimum; where a higher level of protection is desired, such as for hospitals, design levels should be increased to protect against earthquakes with longer recurrence intervals. Design magnitudes recommended for the three levels of use for earthquakes expected from the Sierra Madre, the Whittier, and the San Andreas faults are listed in Table 5 on the next page.

The risk of an earthquake from the San Andreas fault is a special case. As discussed in the previous section, a major or "great earthquake" is considered imminent. As a result, all structures except possibly limited occupancy should be designed for an earthquake of magnitude 8.5 on the San Andreas fault.

TABLE 5

RECOMMENDED DESIGN MAGNITUDES FOR THREE
TYPES OF USE FOR POTENTIALLY DAMAGING
EARTHQUAKES IN EASTERN SAN GABRIEL VALLEY

Use	Approximate Recurrence Interval (years)	Fault (Source of Earthquake)		
		Sierra Madre	Whittier	San Andreas
Limited occupancy (warehouses, automated manufacturing facilities, etc.)	50-100	--*	4.5	8.5
Normal occupancy (residences, normally occupied factories, etc.)	100-200	6.5	5.2	8.5
Critical facilities (hospitals, fire and police stations, schools, critical utilities, etc.)	300-800	7.5	6.0	8.5

* Seismic history of the Sierra Madre fault suggests that smaller earthquakes will probably not occur on this fault.

D. EARTHQUAKE SHAKING

1. Sources of Expected Shaking

The sources of expected earthquakes, their magnitudes, and the risk of their occurring expressed as recurrence intervals has been developed in the previous section. Of the earthquakes discussed, those expected from the Sierra Madre fault system are the most important because of the proximity of the fault system to most of the study area, and the extent of the data that indicates that the fault is active and capable of generating a damaging earthquake.

The Whittier fault is of lesser importance because it is not expected to generate as large a magnitude earthquake as the Sierra Madre fault and it is located outside the study area. However, the Whittier fault is closer to the southern part of the study area than is the Sierra Madre fault, and could be significant there.

The San Andreas fault is located approximately 20 miles to the north of the study area, and the effects of a "great" earthquake (magnitude 8+) on this fault could be comparable to those expected from the Sierra Madre fault. The duration of "strong" shaking of the San Andreas earthquake will be several times longer (40-60 seconds as opposed to 12-15 seconds for the Sierra Madre event) than that of the expected magnitude 6.5 earthquake from the Sierra Madre fault, and its effect on tall buildings in particular could be significant.

The following sections of this report treat the analysis of earthquakes expected from these three faults. Other known active faults in the region, such as the Newport-Inglewood to the southwest or the San Jacinto to the east, are at greater distances from the study area than those being considered, and the effects of expected earthquakes on these faults should be less than those developed for earthquakes from the three subject faults.

2. Intensity of Recorded Eartnquakes

The following is a chronology of earthquakes that have been either widely felt or damaging within the San Gabriel Valley. Prior to about 1932, locations for earthquakes are less certain because they are based on qualitative rather than quantitative observations. Since that time, epicenter locations are assigned from seismograph data, but even these locations may be uncertain by several miles because of the assumptions involved in computing distance from the recorded arrival times.

1769, July 29. This is the first historically recorded California earthquake. It was felt strongly by the Portola expedition camped on the bank of the Santa Ana River, near the present town of Olive. Because the expedition continued to feel aftershocks for several days, it was probably a large event on a distant fault. Speculation is open as to what fault might have been responsible, but there is a suggestion that it may have been the San Fernando fault. The age dating of a fault movement in the San Fernando area as having occurred about 200 years before the 1971 earthquake (Bonilla, 1972) would coincide approximately with this earthquake.

1812, December 8. Based on damage intensity, this earthquake is thought to be located somewhere offshore near San Juan Capistrano. It caused fatal damage at Mission San Juan Capistrano and also caused some damage at Mission San Gabriel. There is not enough evidence to locate the epicenter, or to associate the earthquake to a specific fault.

1855, July 10. Reports suggest this earthquake has important bearing on the risk of strong shaking. Heavier local shaking may have transpired than in the great earthquake of 1857 (see next entry). In the 1855 event, many houses in Los Angeles were damaged, bells were thrown down at San Gabriel Mission, and the Hugo Reid adobe was wrecked. The Hugo Reid adobe has been restored on its original site at the County Arboretum in Arcadia -- directly in the disturbed zone along the Raymond Hill fault. Existing geologic features along this fault strongly suggest a very recent displacement, which might well have been the 1855 event. (We are grateful to Lindvall, Richter and Associates for calling this information to our attention.)

1857, January 9. This great earthquake was accompanied by surface displacements along the San Andreas fault, extending more than 200 miles from the Carrizo Plain in San Luis Obispo County, to San Bernardino. Water came to the surface at points in the San Gabriel Valley, and lurch cracks and possible liquefaction were reported at Temple's Ranch ("La Merced Ranch" at the present site of El Monte) by Barrows (1857). Based on similar length of fault rupture, the magnitude of the event is usually estimated as comparable to that of the San Francisco earthquake of 1906 (8.3).

1899, July 22. Centered near San Bernardino. Slides in Cajon Pass, slight damage as far west as Los Angeles. Probably the largest shock on the southern part of the San Andreas fault since 1857.

1899, December 25. Centered on the San Jacinto fault in the mountains southeast of San Jacinto, where there was much damage, including six fatalities. Felt over most of Southern California.

1910, May 15. The largest earthquake attributable to the Elsinore fault. Damage in Corona area. Felt over a large area; damage in San Gabriel Valley was slight.

1918, April 21. Centered on the San Jacinto fault near San Jacinto. Much small damage reported in Los Angeles.

1929, July 8. Damage in the area of Whittier, Santa Fe Springs, and Norwalk. Magnitude 4.7. The data are not consonant with an epicenter on the Whittier fault, but better fit the Norwalk fault (Richter, 1958). Other earthquakes, mostly smaller, have been assigned epicenters on the Norwalk fault at infrequent intervals.

1933, March 10. The Long Beach earthquake of magnitude 6.3 resulted in intensities of V to VI in the study area. This earthquake is attributed to subsurface faulting along the Newport-Inglewood zone, with the epicenter of the main shock off Huntington Beach.

1952, July 21. A major earthquake (magnitude 7.7) centered in Kern County resulting from displacements on the White Wolf fault. Severe damage at Arvin and Tehachapi with intensities of V-VI in the study area. Expensive interior damage in some of the larger old buildings in Los Angeles region. Notable for geographically wide extent of felt area due to long-period vibrations.

1967, November 12. Minor damage in the Whittier area; magnitude 4.1. Whittier fault probably responsible.

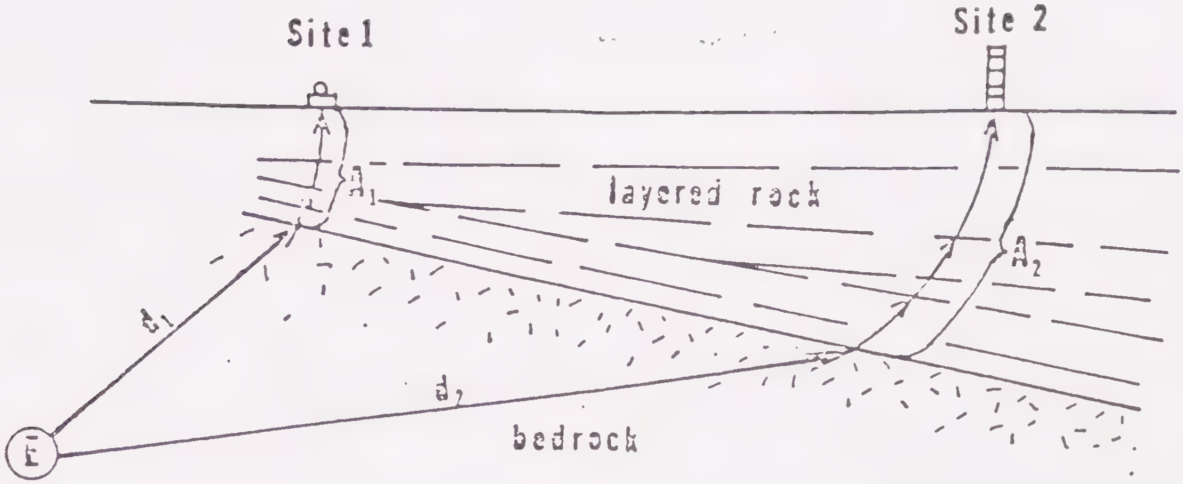
1971, February 9. The San Fernando earthquake of magnitude 6.4. Shaking in the eastern San Gabriel Valley was generally intensity VI, slightly greater than in the Long Beach earthquake of 1933. Several older buildings razed in Pasadena and Glendale area.

The intensity of shaking during past earthquakes can often be used as a rough check on the more quantitative methodology used to derive data useful to engineers, or to detect variations in shaking at different locations on different types of materials. However, the intensities experienced in the eastern San Gabriel Valley in the past have been either too low to be of value in comparing larger intensities of shaking or too early in the history of the area for there to have been an adequate record. The analysis of expected shaking will, therefore, be based primarily on data obtained from the study of comparable earthquakes in other areas.

3. Engineering Characteristics of Expected Earthquakes

a. Methodology

The derivation of the engineering characteristics of a particular earthquake at a particular site is normally a two-step process. These steps are the two considerations that have been discussed in describing the changes in earthquake intensity; that is, distance to the source of the earthquake and local conditions. Where the distance factor is treated as the travel path in deep bedrock, the effect of local conditions is the near-surface amplification of the waves as they travel upward through layered rocks. The mathematics and geometry of this calculation are shown in Figure 18. The distance problem is a relatively simple part of the calculation. However, near-surface amplification and the choice of type earthquakes are more complex problems to be discussed in detail in the next two sections.



The spectrum, S_{V1}, of the earthquake, E, recorded at site 1, at distance d_1 from the source of the earthquake is:

$$S_{V1} = \frac{E\ A_1}{d_1}$$

where A is the near-surface amplification of the bedrock motion, damping in bedrock is negligible, and spreading is cylindrical. Likewise, the spectrum at site 2 is:

$$S_{V2} = \frac{E\ A_2}{d_2}$$

Therefore:

$$S_{V2} = S_{V1}\ \frac{d_1}{d_2}\ \frac{A_2}{A_1}$$

Where S_{V1}, S_{V2}, A_1, and A_2 are complex functions of frequency.

Figure 18. Geometry and mathematics of computation of the engineering characteristics of an earthquake.

b. Near-Surface Amplification

1. Physical Principles

The amplification of earthquake waves traveling through a media of differing physical characteristics (i.e. layered rocks) is based on two physical principles: conservation of energy, and the selective amplification of resonant frequencies.

The principle of conservation of energy applies to the transformation of the physical properties of a wave as it travels from the very fast, dense rocks at depth to the much slower, less dense rocks or soils at the surface. In this conversion, the energy of wave velocity is converted to energy of wave amplitude. The mathematical expression for this change as a wave travels from layer 2 to layer 1 is:

$$AR = \frac{D_2 V_2}{D_1 V_1}$$

where: AR = amplification ratio (layer 2 to layer 1),

D_1 = density of layer 1,

D_2 = density of layer 2,

V_1 = velocity of layer 1, and

V_2 = velocity of layer 2.

The above equation involves both velocity and density, but velocity is by far the most important. In the overall change from granite at depth to an average soil at the surface, the density will typically change from 2.7 to about 1.5; a ratio of less than 2:1. Velocity (shear-wave) on the other hand will typically change from about 11,000 ft/sec to less than 500 ft/sec; a ratio of more than 20:1, and 10 times the density change.

The selective amplification of resonant frequencies is more complex, but in simple terms, the rock layers act somewhat like a series of organ pipes that amplify waves of particular frequencies. The frequencies that are amplified are those that form a one-quarter-wavelength standing wave in the layer, and all higher modes. The dominant periods of a layer are thus:

$$T = \frac{4H}{1V}, \frac{4H}{3V}, \frac{4H}{5V}, \text{etc.}$$

where: T = dominant period,

H = layer thickness, and

V = layer velocity (shear wave).

For most sites, with many layers of varying thickness and a gradual increase of velocity with depth, selective amplification is secondary in importance to the more general amplification due to decreasing velocity and density. However, where there is a very pronounced velocity change at relatively shallow depth, as in the Mexico City area discussed in the Introduction, the concentration of energy in a narrow frequency range can be very important for structures having a similar natural period of vibration.

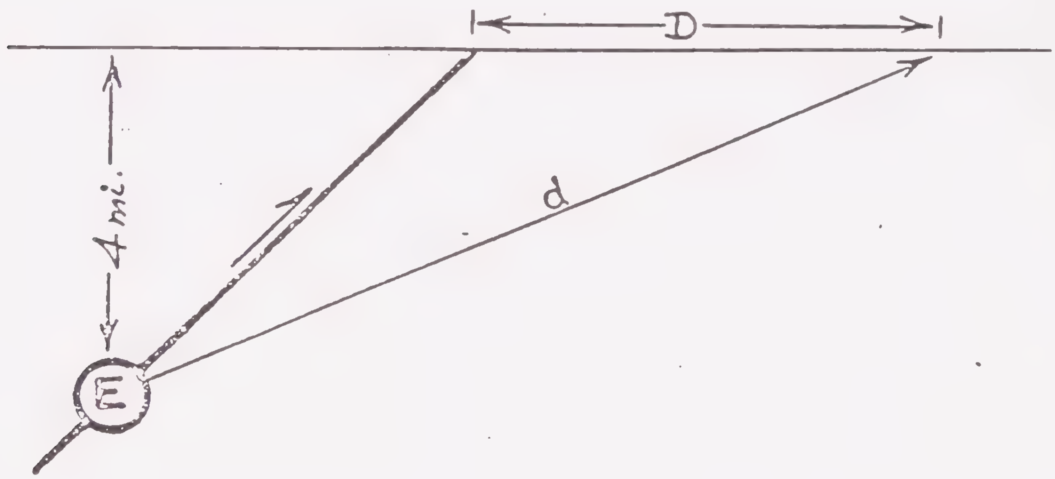
In addition to the two principles considered above, damping can be important for sites with thick layered sequences. Waves traveling in fast, dense rocks such as granite are almost unaffected by damping, but unconsolidated materials such as soils, soft sands and shales can effectively damp earthquake waves if they are present in sufficient thickness. Overall, the effect is to cancel a part of the wave amplification of the slow, less dense rocks, because rocks with high amplification characteristics generally have high damping factors. For damping to be effective, however, thick layers are required. Thus, low velocity materials may be "good" or "bad". If, they are present as a relatively thin layer (15-100 feet), amplification may be very significant. However, if they are present as very thick layers (several thousands of feet), damping can be effective in reducing the amplification normally expected at sites underlain by low velocity rocks.

From the discussion above it is apparent that the most important physical characteristic of a site is the velocity or velocities of the layers underlying the site. Density is less important, and it can be estimated from velocity if the rock types are known. Damping is important for thick sections, and it too is closely related to velocity. Thus, if the velocity of the wave type of interest is known, the density and damping can generally be estimated to an acceptable degree of accuracy.

Earthquake shaking is the result of complex combinations of several types of vibrational waves. The primary components of earthquake waves are the so-called body waves that travel through the deeper parts of the earth's crust. Body waves include

the primary (P-wave) or compressional waves and the secondary (S-wave) or shear waves. For waves traveling at depth, and refracted upward to the site (Figure 19), the P-waves, vibrating parallel to the propagation direction, dominate the vertical component of shaking. The S-waves arrive later and vibrate normal to the direction of propagation; they make up the major part of the damage-inducing, horizontal components of shaking. Thus, it is the shear waves that are of primary importance in the analysis of earthquake shaking.

The Sierra Madre fault is inclined to the north at an angle of approximately 45 degrees. As shown diagrammatically on Figure 19, the inclined fault plane results in longer travel paths for earthquake waves on the south, or valley side, of the fault as compared to the paths for earthquake waves traveling northward from the fault plane. This asymetry about the surface trace of the fault requires modification of the distances used in the computation of the engineering characteristics of earthquakes expected from this source. The required modification is shown below and assumes that the center of the source of shaking is located on the fault plane at a depth of 4 miles.



$$d = \sqrt{16 + (D^2 + 16)}$$

where:

d = modified distance to earthquake center (d_2 of Figure 18) in miles.

D = distance from site to fault trace on surface in miles.

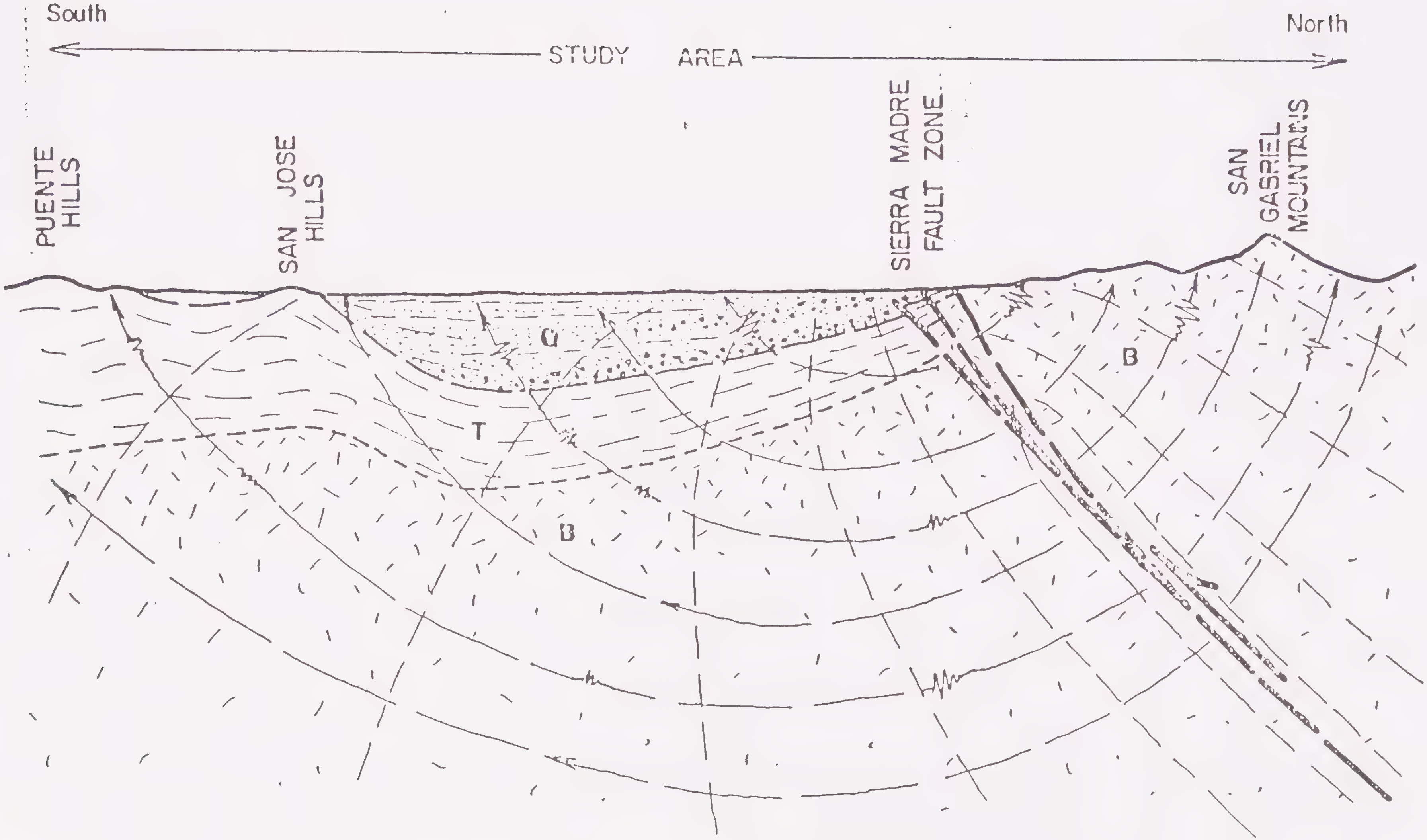


Figure 19. Diagrammatic geologic cross section showing path of earthquake waves from Sierra Madre fault. Note longer paths on south side due to inclined fault plane. Q = Quaternary valley fill; T = Tertiary rocks; B - Basement rocks.

2) Model Analysis

The analysis of near-surface amplification in the study area is based on a series of computer-generated amplification spectra based on models of subsurface conditions. Velocity data from deep wells drilled in or near the study area, generously contributed by Standard Oil Company of California, was sufficient to develop models for four sites as follows:

	Well	Location
1.	Standard #1, Consolidated Rock Products	Sec. 5, T2S, R10W
2.	Standard #1, Ferris and	Sec. 21, T1S, R11W
	Texas Co. #9-1 Puente	Sec. 5, T2S, R10W
3.	Texas Co. #17 Baldwin	Sec. 6, T2S, R11W
4.	Standard #1 Live Oak	Sec. 9, T1S, R11W

The amplification spectra for these models are included as Figures 20 through 23, and the data compiled to generate the spectra are shown on Tables 6 through 9.

In addition to those generated for specific conditions, a series of five amplification spectra were generated for various thicknesses of alluvium over bedrock. Velocity data for specific locations is not available, but the materials are similar to those in other parts of Southern California for which good data is available (Duke and Leeds, 1962 and Duke et al, 1971). These spectra are included as Figures 24 through 28. The application of these and the spectra noted above is discussed in the section of this report on microzonation.

PHYSICAL CHARACTERISTICS OF NEAR-SURFACE AMPLIFICATION MODEL

Site: Standard #1 Consolidated Rock Products — Table: 6

Top of Unit	Geology	Shear-Wave Velocity (ft/sec)	Thickness (feet)	Density (lbs/cu ft)	Damping
0		500	20	115	.02
20		1000	40	115	.02
60		1600	40	120	.02
100		2000	100	120	.02
200		2400	100	125	.02
300	Valley	2700	100	125	.02
400	Fill	3150	240	130	.02
640	(Recent & Pleistocene)	3600	210	130	.02
850		3900	100	135	.02
950		3420	100	135	.02
1050		4400	100	140	.00625
1150		4800	700	140	.00625
1850	base gravels	4300	500	140	.00625
2350		4800	950	140	.00625
3300		3750	470	140	.00625
3770	Top Mohnian	6000	480	145	.00625
4250		5000	210	145	.00625
4460		6000	640	145	.00625
5100		5500	860	145	.00625
5960		6450	340	150	.00625
6300		7700	1200	150	.00625

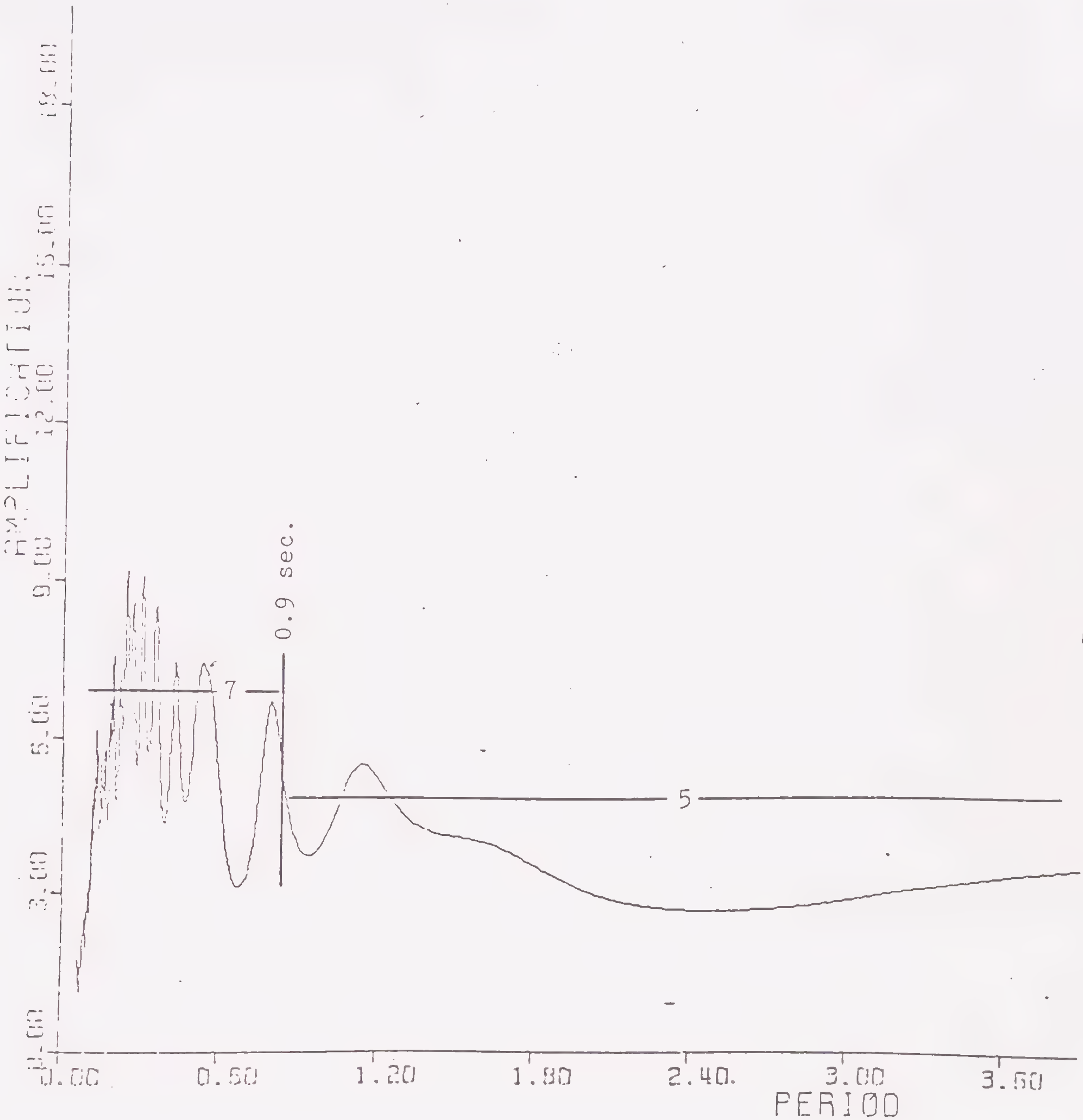


Figure 20. Amplification spectrum at site of Standard Oil Co. #1 Consolidated Rock Products well in Section 5, T2S, R10W.

PHYSICAL CHARACTERISTICS OF NEAR-SURFACE AMPLIFICATION MODEL

Site: Standard #1 Ferris　　　　Table: 7

Top of Unit	Geology		Shear-Wave Velocity (ft/sec)	Thickness (feet)	Density (lbs/cu ft)	Damping
0			765	40	115	.02
40			1800	60	120	.02
100		from	2700	100	125	.02
200		Texas #9-1 Puente	2880	200	130	.02
400	Valley		2970	200	130	.02
600	Fill		3150	400	135	.02
1000			3625	250	135	.02
1250			3850	575	135	.02
1825			4400	675	140	.00625
2500			4775	1010	140	.00625
3510			5450	440	145	.00625
3950			4550	960	140	.00625
4910			6550	850	145	.00625
5760			5350	1055	145	.00625
6815			8000	100	150	.005
6915			5300	275	145	.00625
7190			5700	1350	145	.00625
8540	Tertiary		7500	710	150	.00625
9250			9200	160	150	.005
9410			8000	910	150	.005
10,320			7500	790	150	.005
11,110			8600	950	150	.005
12,060	Basement		11,800	10,000	155	.00385

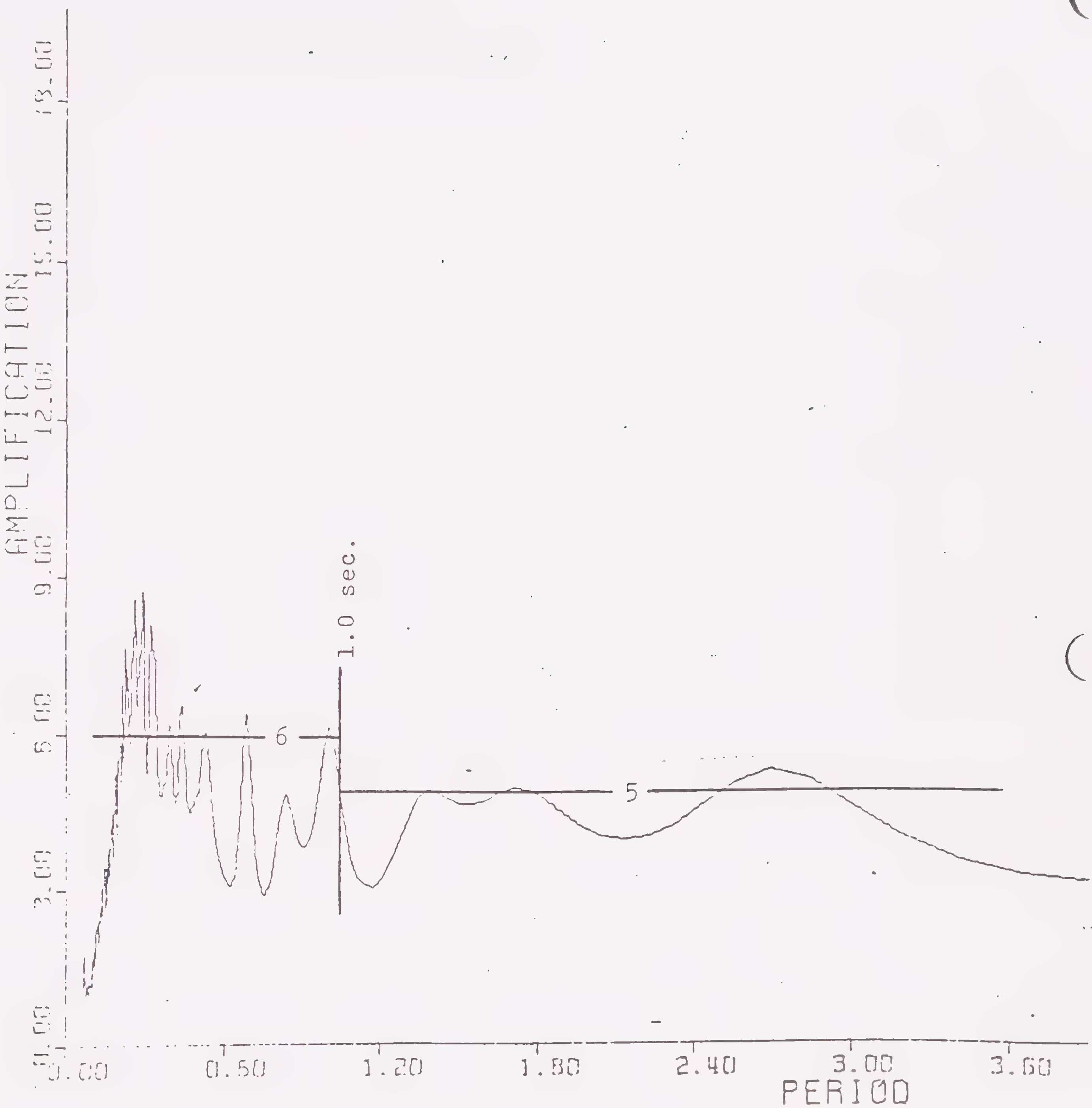


Figure 21. Amplification spectrum at site of Standard Oil Co. #1 Ferris well in Section 21, T1S,R11W.

PHYSICAL CHARACTERISTICS OF NEAR-SURFACE AMPLIFICATION MODEL

Site: Texas Co. #17 Baldwin Table: 8

Top of Unit	Geology	Shear-Wave Velocity (ft/sec)	Thickness (feet)	Density (lbs/cu ft)	Damping
0		3150	500	130	.00625
500		3780	500	135	.00625
1000		3400	500	140	.00625
1500	Repetto	4950	500	140	.00625
2000	(Pliocene)	3900	500	140	.00625
2500		4450	500	145	.00625
3000		4000	500	145	.00625
3500		4450	500	145	.00625
4000		6100	500	145	.00625
4500	Upper Puente	4575	500	145	.00625
5000	(miocene)	6450	500	150	.00625
5800		11800	800	150	.00625

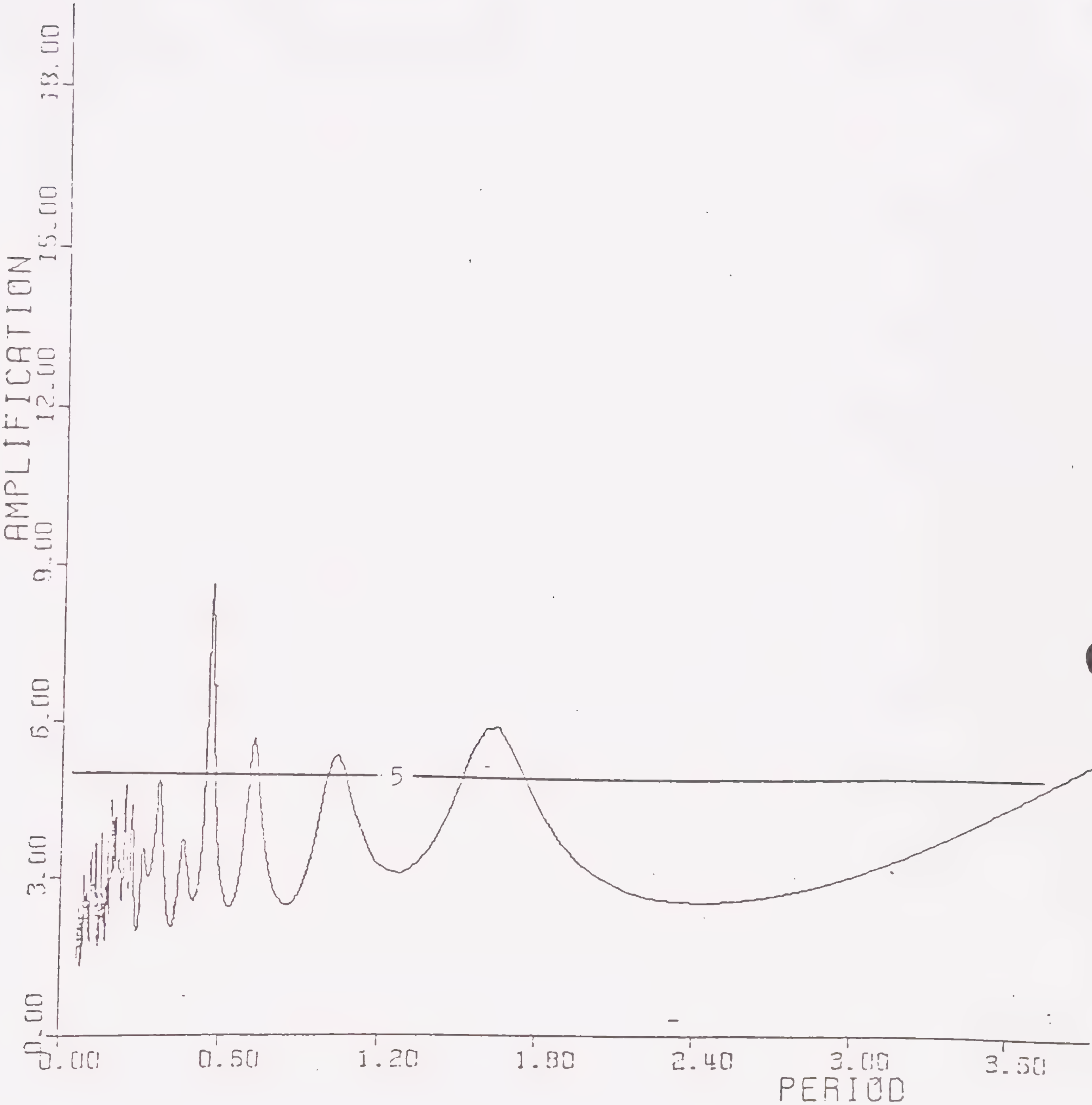


Figure 22. Amplification spectrum at site of Texas Co. #17 Baldwin in Section 6, T2S, R11W.

PHYSICAL CHARACTERISTICS OF NEAR-SURFACE AMPLIFICATION MODEL

Site: Standard - Live Oak #1 Table: 9

Top of Unit	Geology	Shear-Wave Velocity (ft/sec)	Thickness (feet)	Density (lbs/cu ft)	Damping
0		800	20	115	.02
20		1200	40	115	.02
60		2000	45	120	.02
105		2600	40	120	.02
145		2400	65	125	.02
210	Valley	2610	150	125	.02
360	Fill	2970	150	125	.02
510	(Recent & Pleistocene)	2900	400	130	.02
910		3300	265	130	.02
1175		4000	835	135	.00625
2010		4760	920	140	.00625
2930		5000	570	145	.00625
3500	base gravels	5260	660	145	.00625
4160		4250	490	140	.00625
4650		3925	500	140	.00625
5150		4480	500	140	.00625
5650		5170	500	145	.00625
6150	Tertiary	5000	500	145	.00625
6650		5200	500	145	.00625
7150		5600	500	145	.00625
7650		6100	500	150	.00625
8150		6500	500	150	.00625
8550	Basement	11,000	10,000	155	.00385

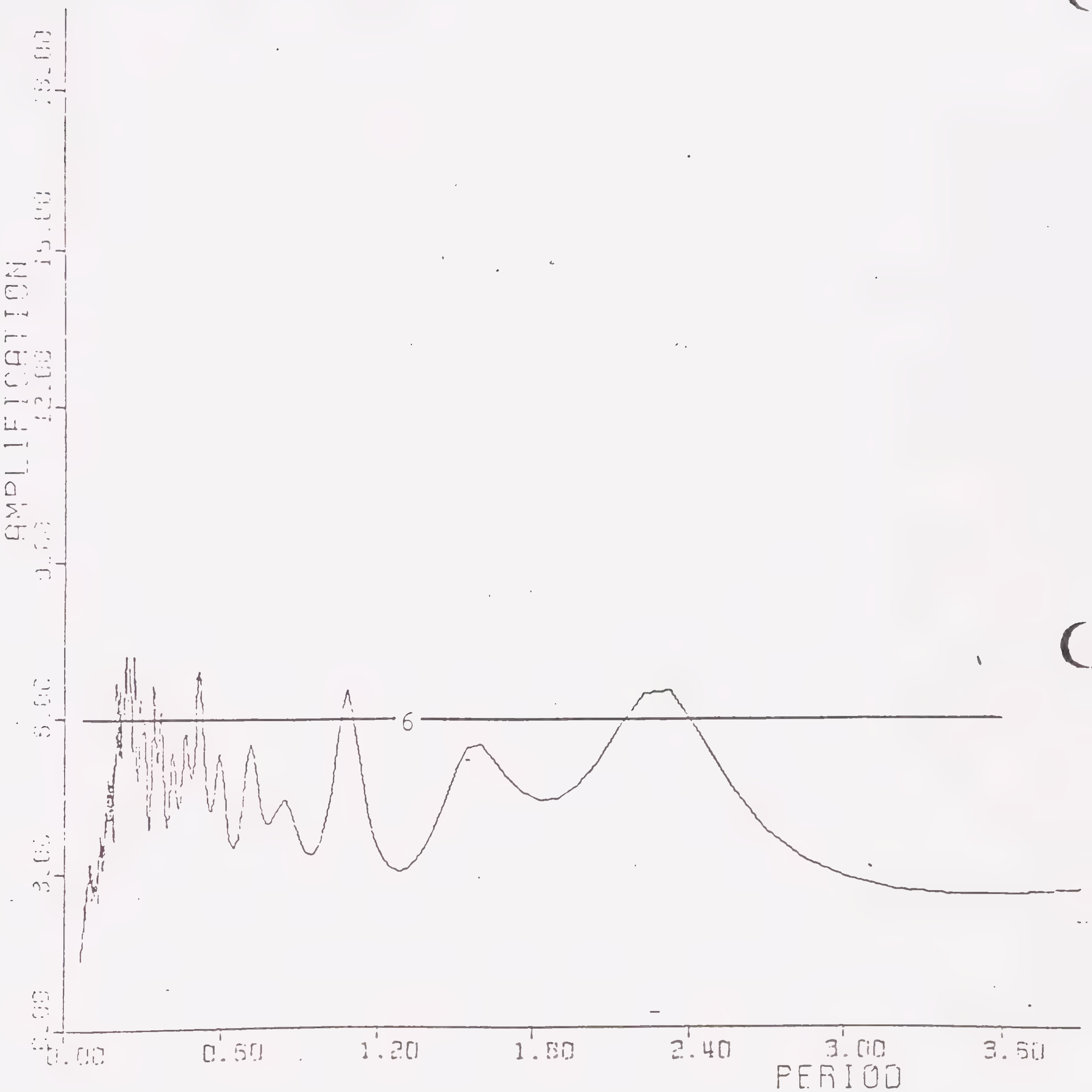


Figure 23. Amplification spectrum at site of Standard Oil Co. #1 Live Oak well in Section 9, T1S, R11W.

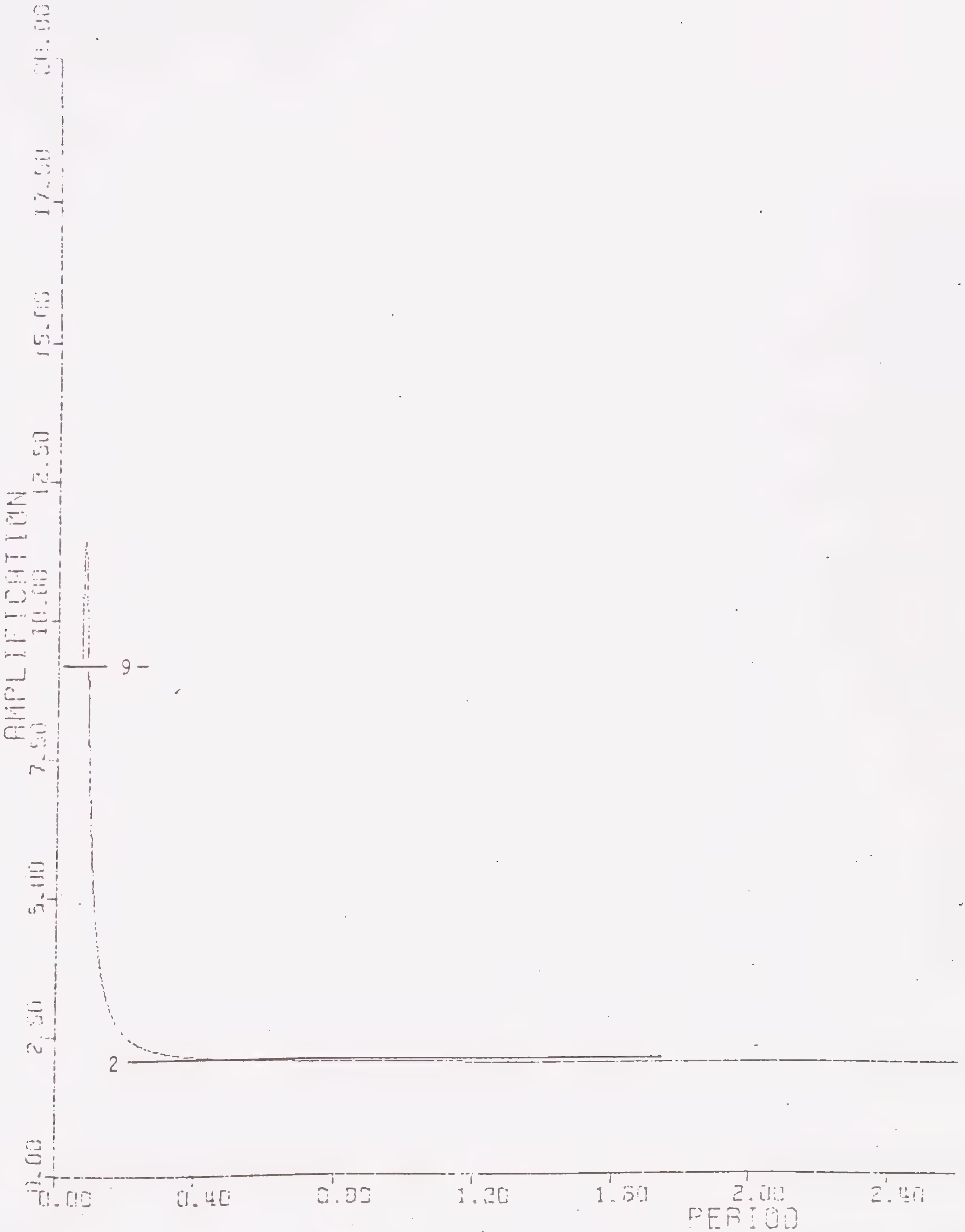


Figure 24. Amplification spectrum for bedrock site condition with 25 feet of weathered material over hard rock

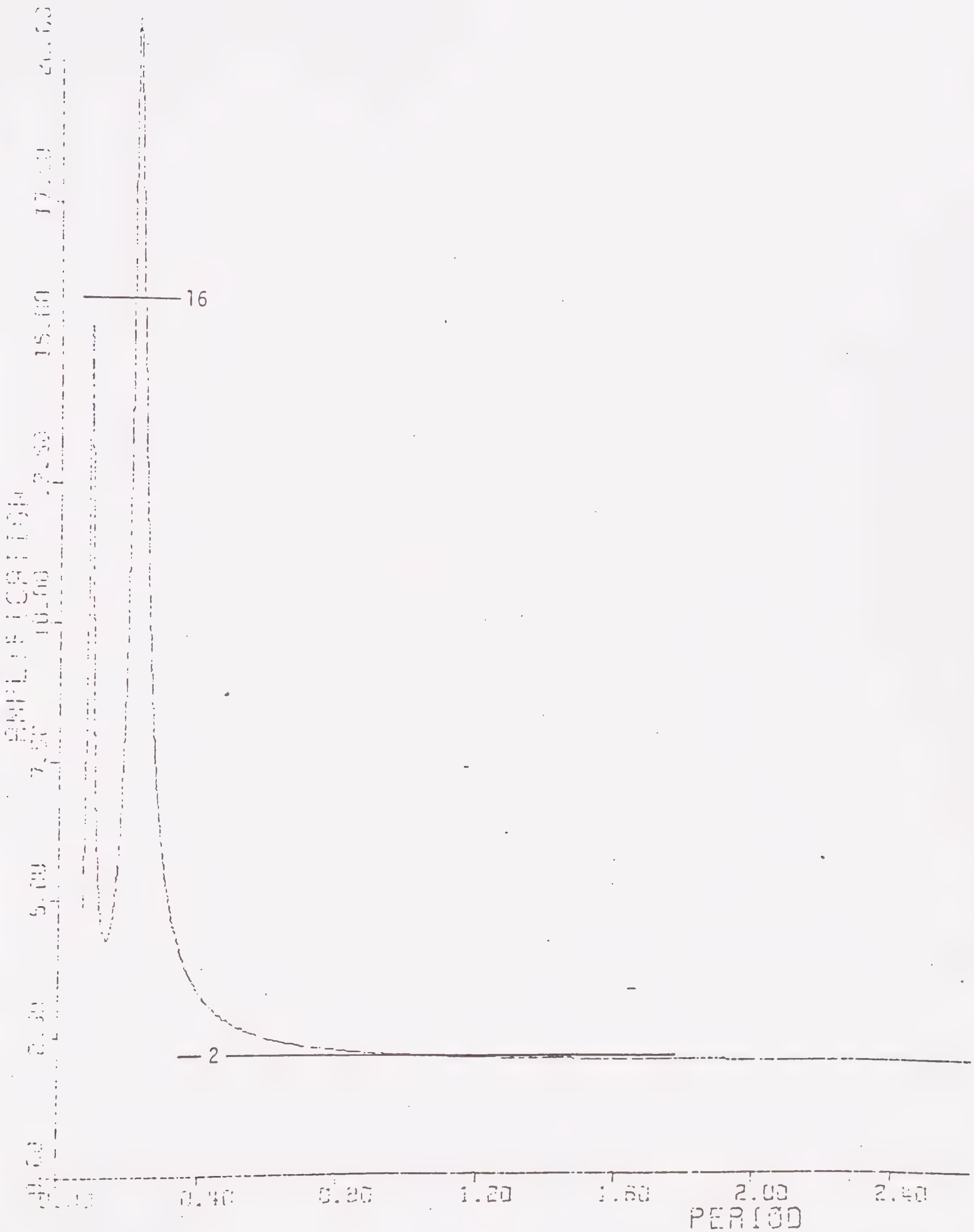


Figure 25. Amplification spectrum for 60 feet of alluvium over hard bedrock

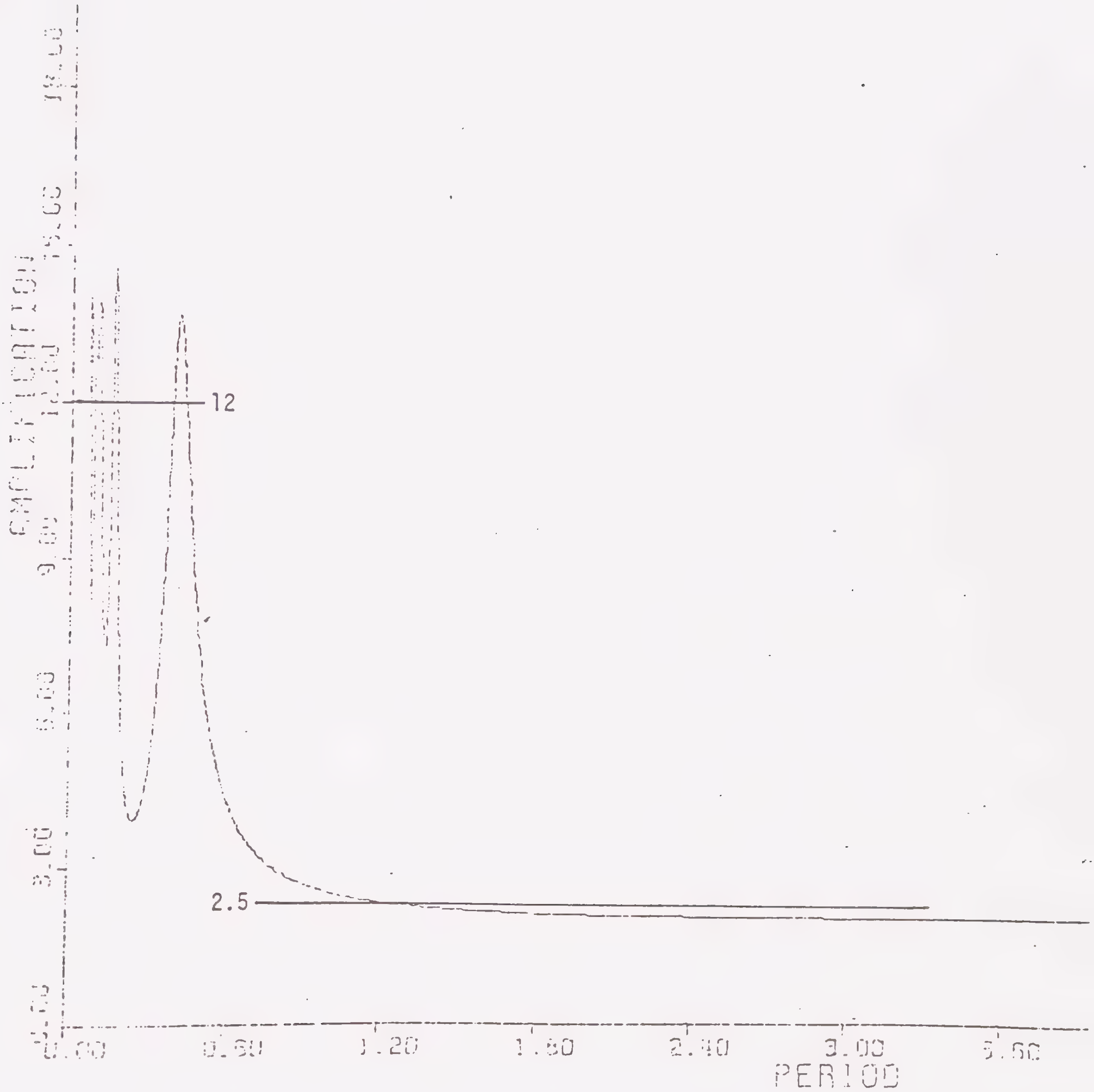


Figure 26. Amplification spectrum for 200 feet of alluvium over hard bedrock

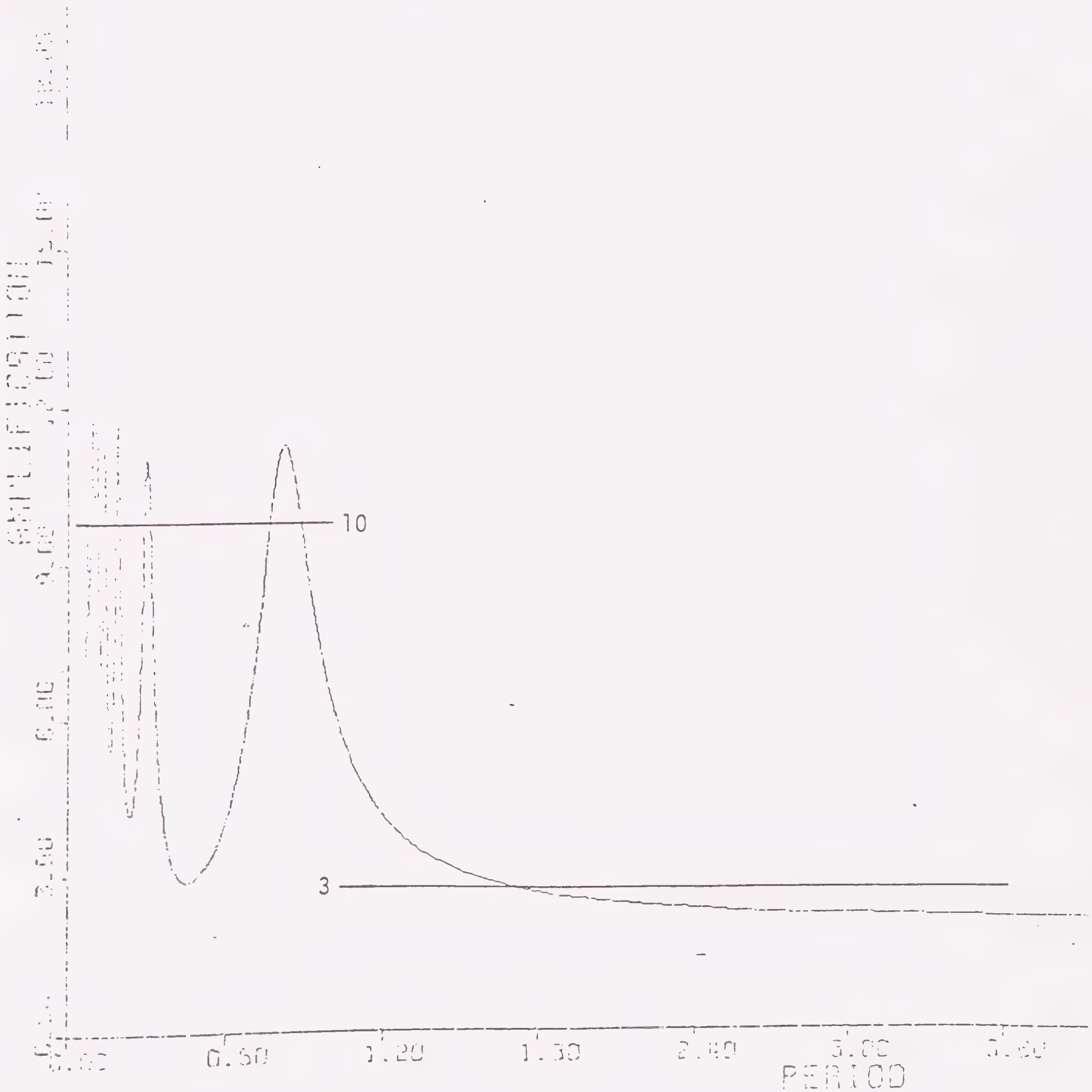


Figure 27. Amplification spectrum for 500 feet of alluvium over hard bedrock

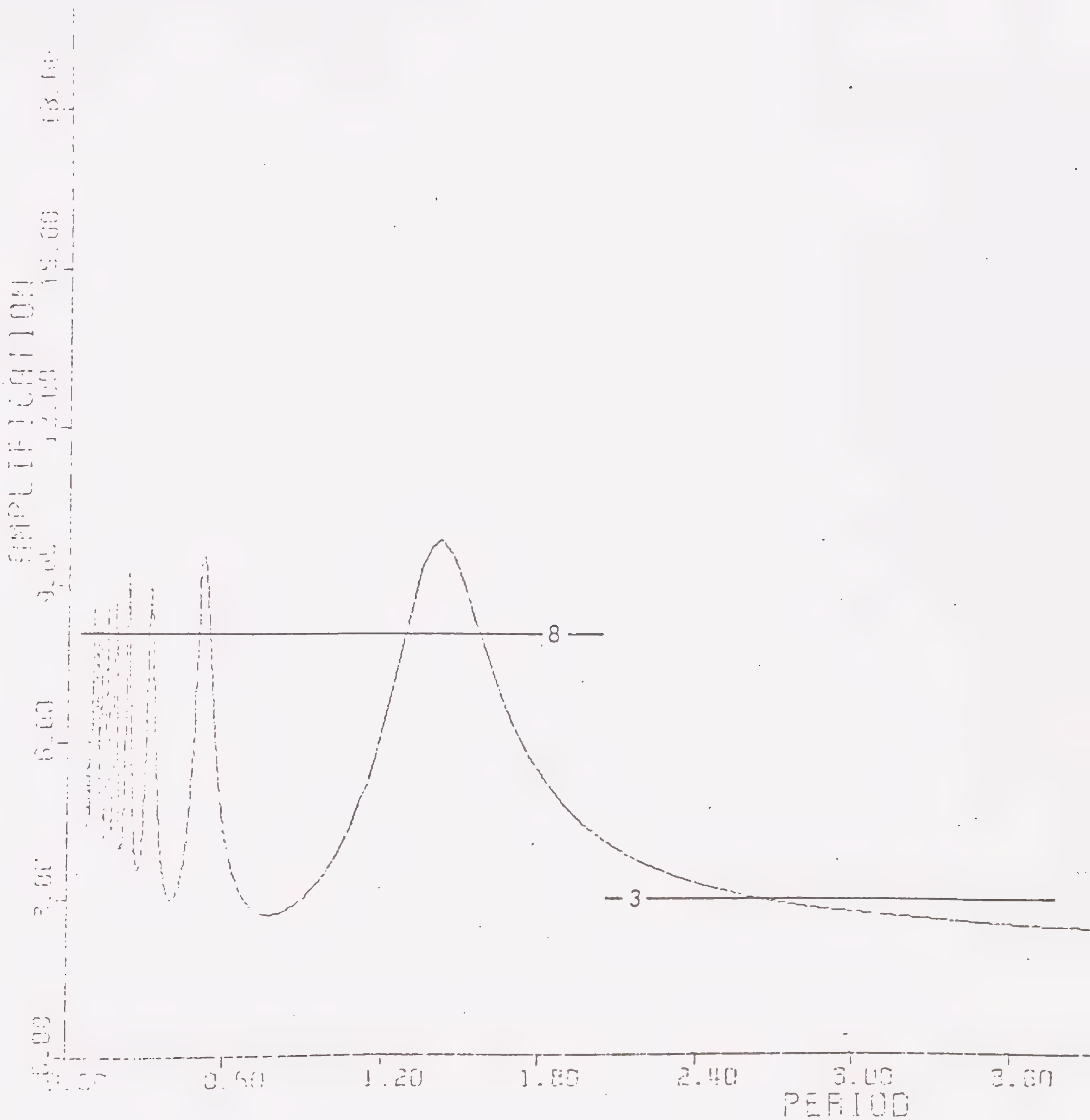


Figure 28. Amplification spectrum for 1000 feet of alluvium over hard bedrock

c. Type Earthquakes

Earthquakes to be considered in the analysis of expected ground shaking include magnitude 6.5 and 7.5 events on the Sierra Madre fault, a magnitude 8.0 to 8.5 event on the San Andreas fault, and magnitude 5.2 and 6.0 events on the Whittier fault. Of these events, the magnitude 6.5 earthquake on the Sierra Madre fault is by far the most important. It is the closest active fault to most of the study area, and the recent San Fernando earthquake has demonstrated the destructive capability of such an event.

Numerous strong-motion records are available for this type of earthquake. The San Fernando earthquake is a good analogy, as this event occurred on a fault with similar characteristics, was of a comparable magnitude, and the overall characteristics of the study area are similar to those of the San Fernando Valley. Of the available strong-motion records, three stand out as being particularly applicable to the problem. Pacoima Dam is located on bedrock and just a few miles north of the fault. Because of the northward inclination of the plane of the fault, this site is generally considered as being near the center of the energy released by the rupture of the fault. The response spectrum of one component of the accelerogram recorded at this site is included as Figure 29. The dashed curves added to the spectrum are smoothed envelopes of both horizontal components for 0, 5, and 10% of critical damping. This spectrum is considered a good analogy to the ground motion that should be expected on bedrock in that part of the study area just north of the Sierra Madre fault.

Of the accelerographs located in the valley area south of the fault, the closest to the fault is the Holiday Inn located at 8244 Orion Boulevard. The response spectrum of one component of this accelerogram is included as Figure 30. It is considered a good analogy to the ground motion that should be expected on deep alluvium approximately 5 miles south of the Sierra Madre fault.

Site conditions along the south edge of the San Gabriel Valley are similar to conditions along the south edge of the San Fernando Valley where several accelerographs were located. Of those available, the accelerogram recorded at 15250 Ventura Boulevard is considered average for the area. The response spectrum for one component is included as Figure 31. It is considered a fair analogy to the ground motion that should be expected on relatively thin alluvium about 9 miles from the Sierra Madre fault.

RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

IIIC041 71.001.0 PACOIMA DAM, CAL. COMP S14W

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

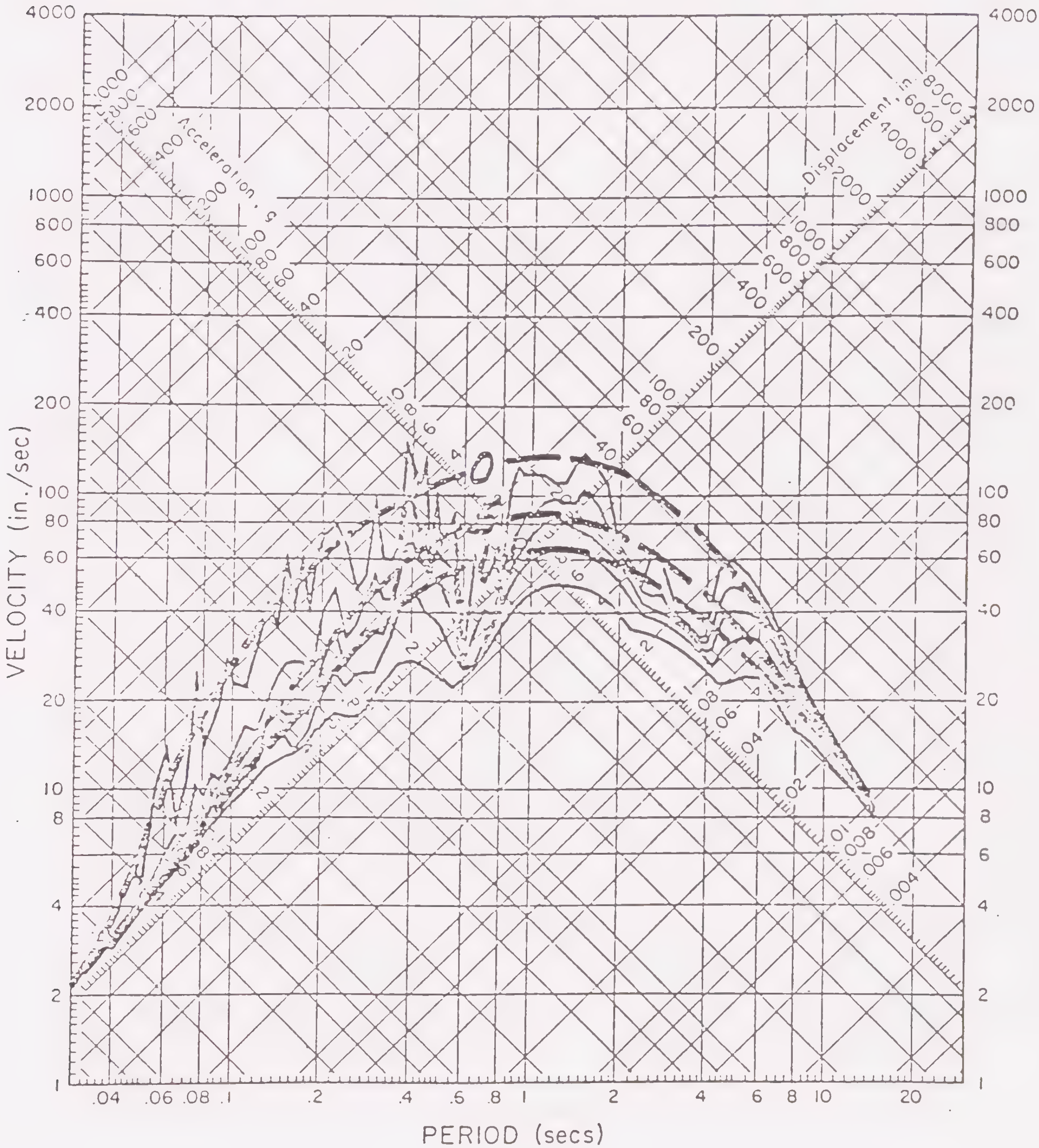


Figure 29. Response spectrum for San Fernando earthquake at Pacoima Dam. Dashed curves are smoothed envelopes for 0, 5, and 10% of critical damping.

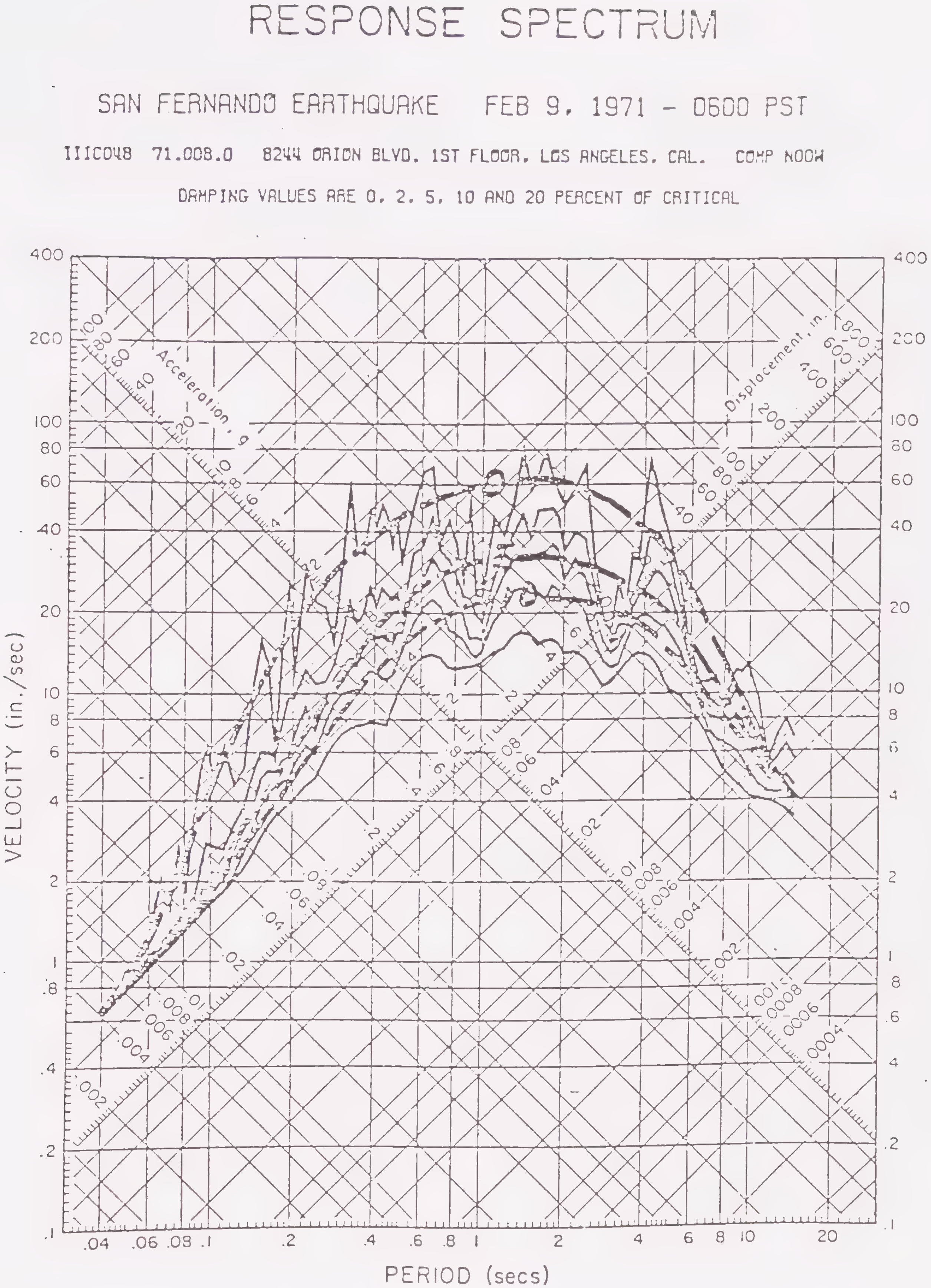


Figure 30. Response spectrum for San Fernando earthquake at 8244 Orion Blvd. in central San Fernando Valley. Dashed curves are smoothed envelopes for 0, 5, and 10% of critical damping.

RESPONSE SPECTRUM

SAN FERNANDO EARTHQUAKE FEB 9, 1971 - 0600 PST

IIIH115 71.024.0 15250 VENTURA BLVD.. BASEMENT. LOS ANGELES. CAL. COMP N11E

DAMPING VALUES ARE 0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

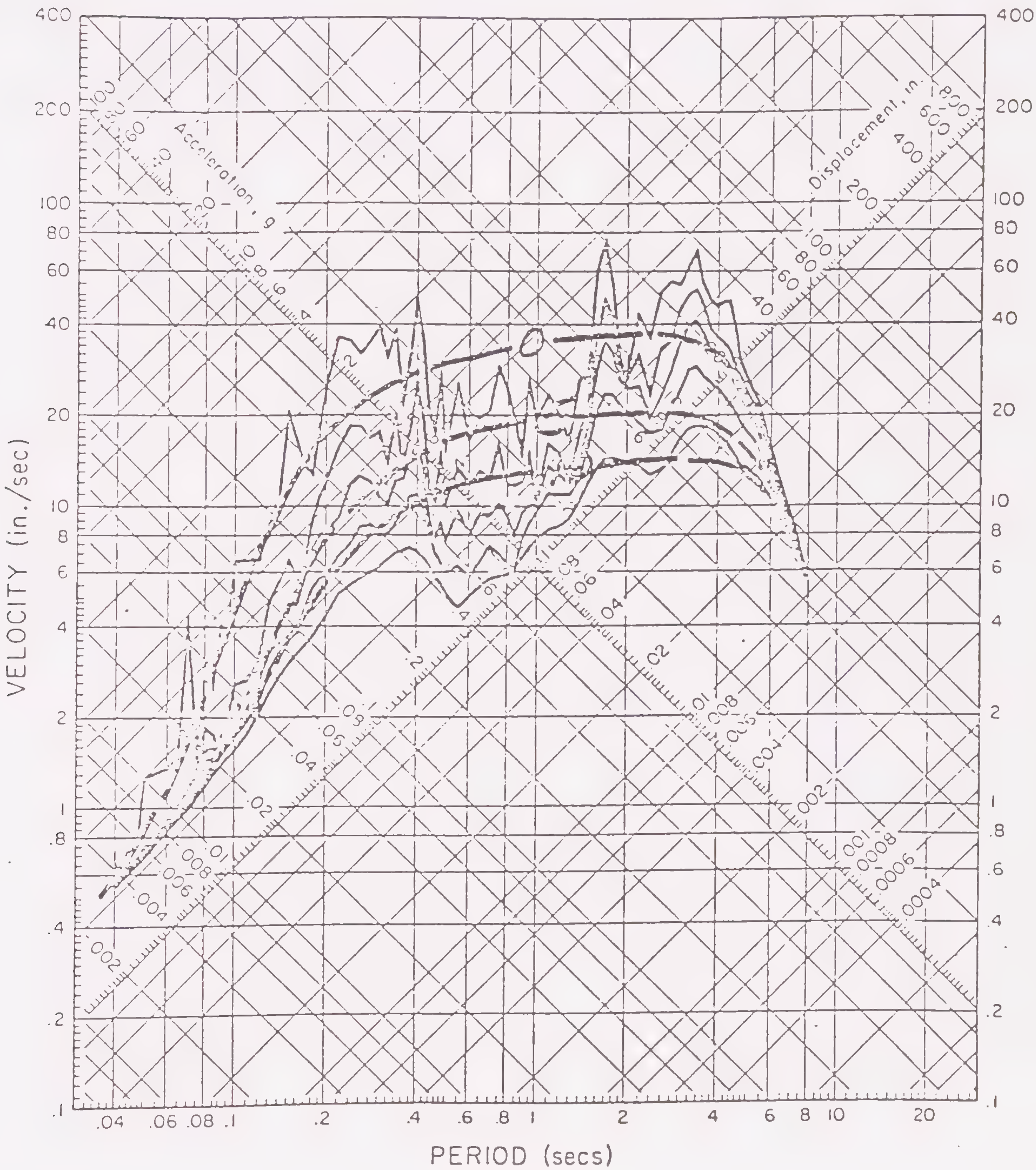


Figure 31. Response spectrum for San Fernando earthquake at 15250 Ventura Blvd. in southern San Fernando Valley. Dashed curves are smoothed envelopes for 0, 5, and 10% of critical damping.

Availability of good records for the larger 7.5 magnitude earthquake that could occur on the Sierra Madre fault is a more difficult problem. The 1952 Kern County earthquake was a comparable magnitude (7.7), but the nearest accelerograph was in Taft, approximately 28 miles away. The adjustment of the spectra of the Taft accelerograms from this distance to the near-zero distances involved in this problem using the methodology discussed previously is not recommended. Instead the spectral values for the magnitude 7.5 event are derived from those of the magnitude 6.5 event, for which there are good records close to the fault, by scaling them upward using the ratios of the attenuation curves of Schnabel and Seed (1972) for the two events of these magnitudes.

The San Andreas fault is located approximately 20 miles north of the Sierra Madre fault, but the magnitude 8.0-8.5 earthquake expected on this fault should be of considerably longer duration than either earthquake expected on the Sierra Madre fault. The effects should be less than those expected from the Sierra Madre fault in the northern zones (I, II, and possibly III), but may be greater in the southern zones (IV, V and possibly III).

The strong motion of an earthquake comparable to the magnitude 8.0 to 8.5 earthquake expected from the San Andreas fault has not been recorded. To fill this gap, the motion has been simulated by Jennings, Housner and Tsai (1968) and by Seed and Idriss (1969) using the records of the larger earthquakes (e.g. Taft record of the Arvin-Techachapi earthquake) and theory regarding the variation in earthquake characteristics with increasing magnitude. The results of the two studies are very similar. The response spectra of the two simulated motions agree well up to a period of about 2.0 seconds, but for the longer periods the motion proposed by Seed and Idriss has substantially lower response. The motion proposed by Jennings, Housner and Tsai has been used in this study because it assumes a site on firm alluvium which better fits the more populated parts of the area. The response spectrum for one component of this motion is included as Figure 32. In addition to the actual response for the various damping factors, smoothed envelopes of both horizontal components (A-1 and A-2) for 0%, 5%, and 10% of critical damping have been added as dashed curves. It is these smoothed response curves that will be used as the response spectrum of the "type earthquake" in the analysis of shaking expected from the San Andreas fault.

A similar situation exists with regard to the magnitude 6.0 and 5.2 events that could occur on the Whittier fault to the south of the study area. The magnitude 5.2 event should be centered at considerable depth, and its effects even in the southern part of the study area should not significantly exceed those of the magnitude 6.5 event on the Sierra Madre fault. The magnitude 6.0 event on the Whittier fault, however, would effect the southernmost zone because fault rupture, and, therefore, the

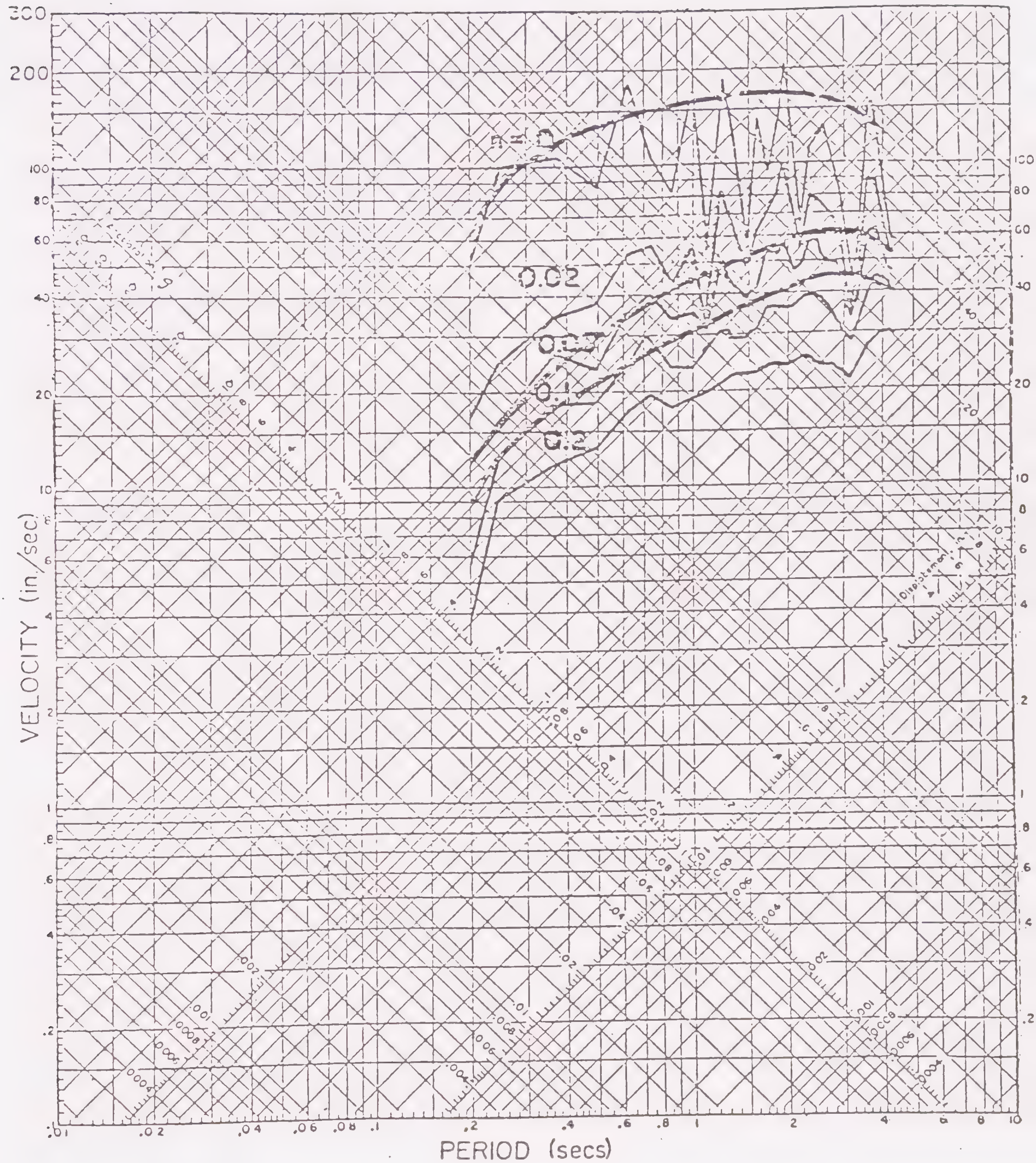


Figure 32. Response spectrum for simulated earthquake A-1 of Jennings, Housner & Tsai, 1968. Dashed curves are smoothed envelopes of A-1 and A-2 spectra for 0, 5, and 10% critical damping.

source of the earthquake waves, would extend to or very near the surface. The maximum ground accelerations for such an earthquake in the southern zone would be about the same as those of the magnitude 7.5 event from the Sierra Madre fault in the next zone to the north. For the level of risk recommended for critical facilities, the effect of the Whittier fault is to combine the two southern zones into one zone for which the shaking characteristics as derived for the earthquake on the Sierra Madre fault should be adequate.

d. Microzonation

As discussed previously in the section on methodology earthquake shaking is dependent on both distance and site conditions. The microzonation, as developed herein, is also based on these two parameters. The zone boundaries based on distance from the fault are somewhat arbitrary, and they have been chosen such as to include a range of parameters comparable to the accuracy of the method.

Five zones based on distance are shown on Plate I. Based on experience from the San Fernando earthquake, a distinction is made between sites on the downthrown (south) and upthrown (north) side of the fault. The shaking characteristics of the latter are based on the data from Pacoima Dam, while those of the former are derived from records of shaking from valley sites.

Site conditions in the study area can be divided into two basic types: bedrock of metamorphic, granite or sedimentary rock, and alluvial areas. The response of the bedrock will vary somewhat depending on its type and on the degree of and thickness of weathering, but this will be minor in comparison to the large differences between bedrock and alluvial sites.

The response of relatively thick sections of alluvium (approximately 2000 to 4000 feet thick) overlying sedimentary bedrock is indicated by the near-surface amplification models based on the four deep wells in the area. While the results vary slightly depending on details of the site conditions, the generalized amplification levels are reasonably constant at about 6 for short periods (0-1.0 sec.) and 5 for longer periods of motion.

The response of varying thicknesses of alluvium was investigated using the near-surface amplification models of Figures 24 through 28. Models were computed for 0, 60, 200, 500, and 1000 feet of alluvium over bedrock, with the results varying in a logical and regular manner. The thin alluvium is characterized by a strong amplification in the low-period (high frequency) range. Increasing the thickness of alluvium decreases the amount of amplification but also "spreads it out" over an increasingly high range of periods (lower frequencies). The variations in amplification between thicknesses of alluvium of about 200 to 1000 feet are

considered as within a range that can reasonably be lumped within one zone. At thicknesses of less than 200 feet the condition known as the "edge effect" becomes pronounced, and the amplification approximately doubles in the range of periods that is most significant for the low-rise construction (less than 5 stories). The models can be generalized as follows:

Thickness of Alluvium (feet)	Short-Period Amplification Factor	Transition Period (Seconds)	Long-Period Amplification Factor
0	3	0.1	2
0 (with 25' weathered layer)	9	0.1	2
60	16	0.3	2
200	12	0.5	2.5
500	10	1.0	3.0
1000	8	1.8	3.0

The models used above are based on alluvium overlying directly a hard granite bedrock. As indicated by the amplification spectra based on well control, the presence of the sedimentary bedrock tends to reduce the velocity contrast and thus reduce the contrast between the long and short-period factors. These two sets of amplification factors can be combined as follows:

Zone Designation and Characteristic	Short-Period Amplification Factor	Transition Period (Seconds)	Long-Period Amplification Factor
C Bedrock (firm to hard)	4	0.2	2-3*
B Alluvium, 200' or less	9	0.1 - 0.5	4
A Alluvium, more than 200'	6	1.0	5

* Granitic and metamorphic bedrock types are assigned a value of 2, and sedimentary types a value of 3.

In addition to the zone types described above, a firmer alluvium is present as old terrace deposits at some locations near the bedrock/alluvium contact. The characteristics of this material are such that they reduce the amplification to levels comparable to that of the thick alluvium, and the thin alluvium zones have been deleted in these areas.

The five zones based on distance and the three types of zones based on rock type are combined using Roman numerals for the distance designation and letters for site character as noted in the table above. Of a possible 15 zones, only 13 are actually present. The areal distribution of the zones is shown on Plate I, and the general characteristics of shaking are summarized in Table 10. Spectra for the magnitude 6.5 earthquake in each zone are shown on Figures 33 through 44, and the necessary adjustment factors to obtain spectral values for the magnitude 7.5 earthquake are given in Table 10.

TABLE 10. GENERALIZED CHARACTERISTICS OF EXPECTED EARTHQUAKES

	Critical Facilities (Based on Magnitude 7.5 earthquake on Sierra Madre fault. 1)				Normal Occupancy (Based on magnitude 6.5 earthquake on Sierra Madre fault. 2)				Limited Occupancy (Based on magnitude 8.5 earthquake on San Andreas fault.)			
Zone	g	T	t	S	g	T	t	S	g	T	t	S
I B	1.3±	0.1-0.3	30-40	33x1.11	1.2±	0.1-0.3	15-20	33	0.35	0.2-0.4	40-50	45
I C	1.3±	0.1-0.3	30-40	33x1.11	1.2±	0.1-0.3	15-20	33	0.25	0.2-0.3	40-50	46
II A	0.47	0.3-0.5	20-30	34x1.30	0.36	0.3-0.5	12-15	34	0.29	0.2-0.4	40-50	47
II B	0.78	0.2-0.4	20-30	35x1.30	0.60	0.2-0.4	12-15	35	0.48	0.2-0.4	40-50	45
II C	0.34	0.4-0.6	20-30	36x1.30	0.26	0.4-0.6	12-15	36	0.21	0.2-0.3	40-50	48
III A	0.38	0.3-0.5	20-30	37x1.34	0.28	0.3-0.5	12-15	37 (2)	0.26	0.2-0.4	40-50	49
III B	0.63	0.2-0.4	20-30	38x1.34	0.47	0.2-0.4	12-15	38 (2)	0.44	0.2-0.4	40-50	50
IV A	0.31	0.3-0.5	20-30	39x1.41	0.22	0.3-0.5	12-15	39 (2)	0.24	0.2-0.4	40-50	51
IV B	0.49	0.2-0.4	20-30	40x1.41	0.35	0.2-0.4	12-15	40 (2)	0.38	0.2-0.4	40-50	52
IV C	0.24	0.4-0.6	20-30	41x1.41	0.17	0.4-0.6	12-15	41 (2)	0.19	0.2-0.3	30-40	53
V A	0.31 (1)	0.3-0.5	20-30	39x1.41	0.21 (2)	0.2-0.4	30-40	42 (2)	0.21	0.2-0.4	30-40	54
V B	0.49 (1)	0.2-0.4	20-30	40x1.41	0.26 (2)	0.2-0.4	40-50	43 (2)	0.34	0.2-0.4	40-50	55
V C	0.24 (1)	0.4-0.6	20-30	41x1.41	0.18 (2)	0.2-0.3	30-40	44 (2)	0.16	0.2-0.3	30-40	56

g = Maximum ground acceleration expressed as a decimal fraction of the acceleration of gravity

T = Predominant period of ground shaking in seconds

t = Duration of "strong" shaking in seconds

S = Figure number for applicable response spectra. Amplification factor for spectral values

Note: 1. Shaking from the earthquake on the Whittier fault exceeds that expected from the Sierra Madre fault in Zone V.

2. See also spectral values for magnitude 8.5 earthquake on San Andreas fault. Shaking from the earthquake on the San Andreas fault exceeds that expected from the Sierra Madre fault in Zone V and in some cases in Zones IV and III. Spectra for magnitude 6.5 earthquake are included for comparison with magnitude 8.5 earthquake.

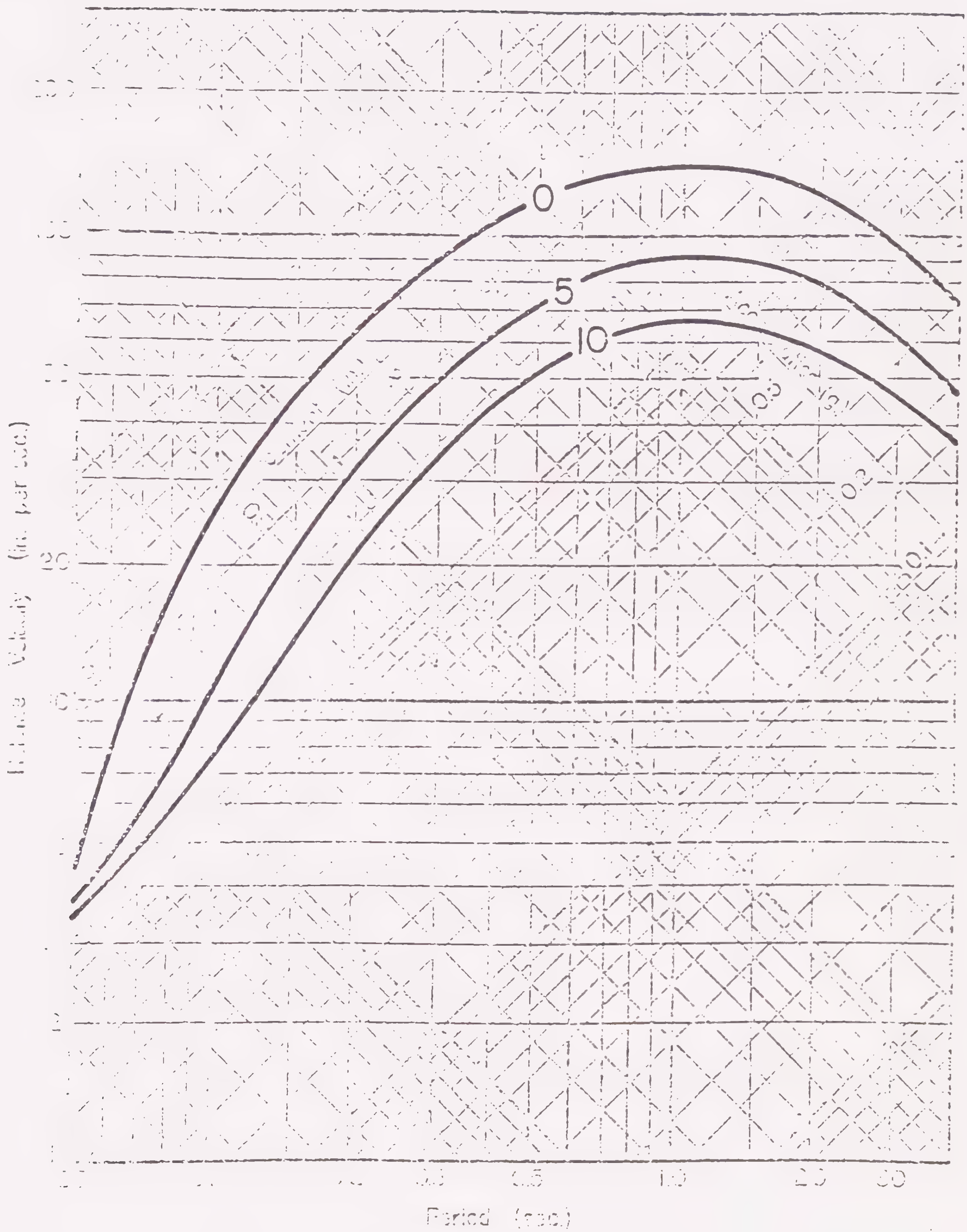


Figure 33. Response spectrum for Zones IB and IC for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5, and 10% critical damping.

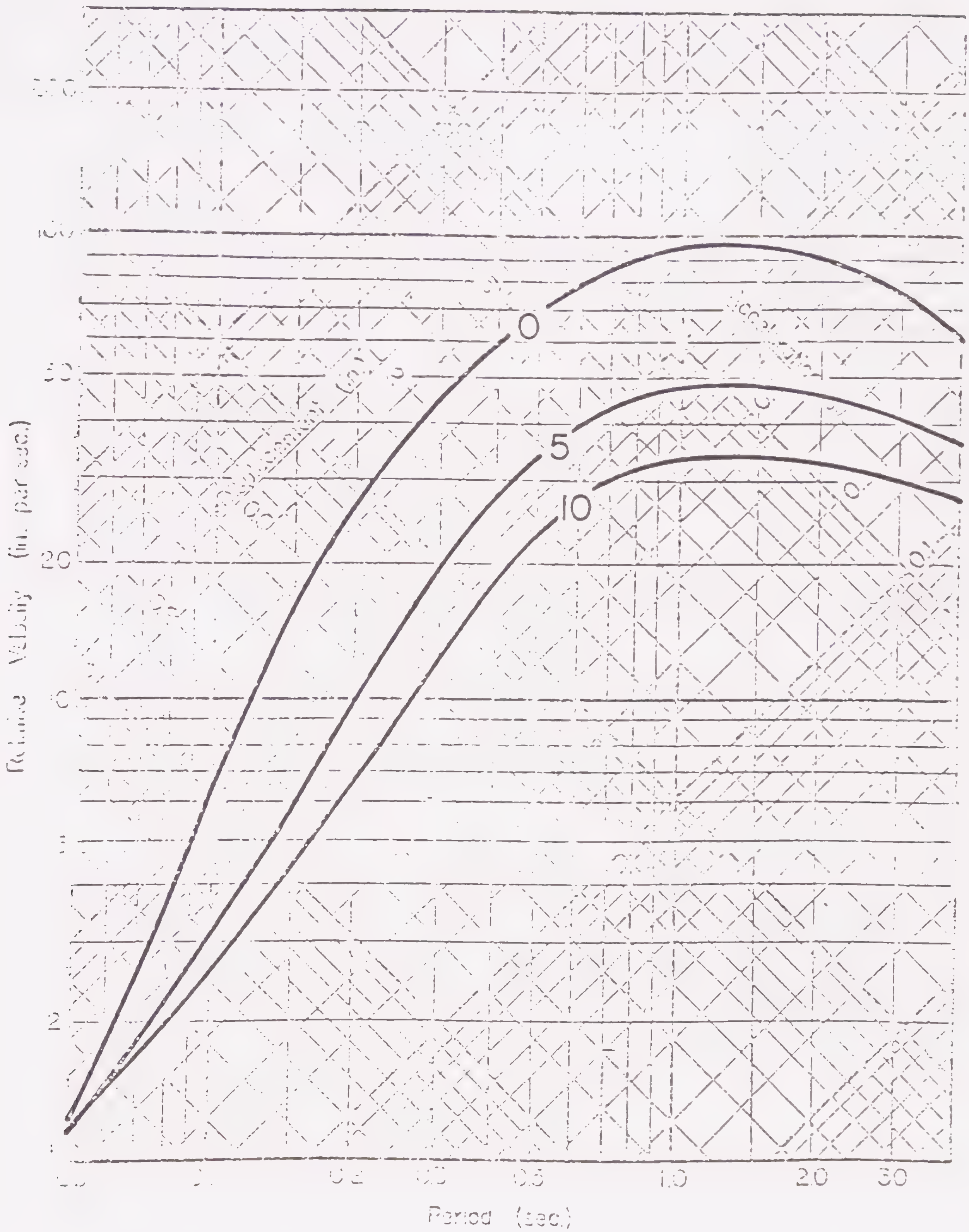


Figure 34. Response spectrum for Zone IIA for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

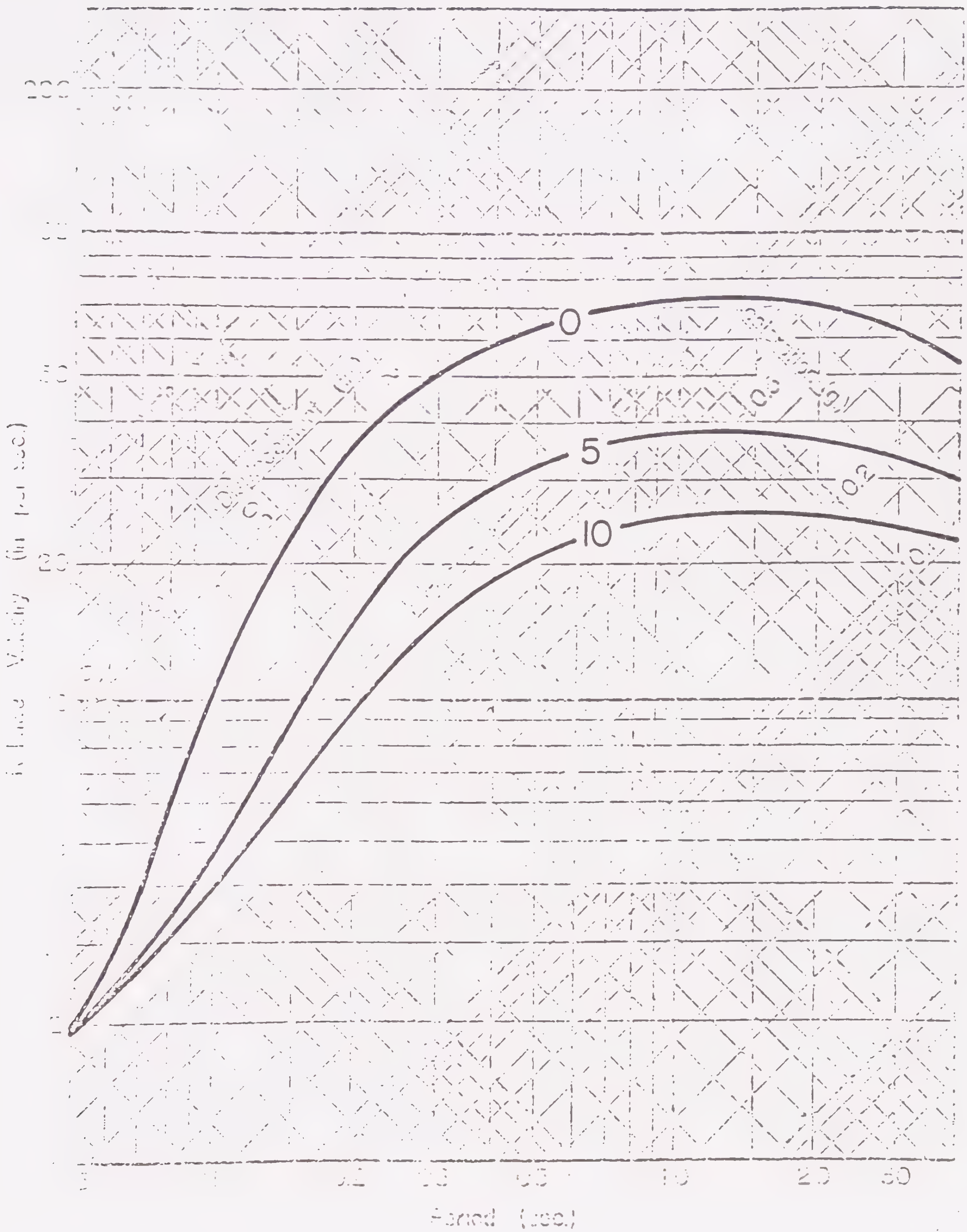


Figure 35. Response spectrum for Zone IIB for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

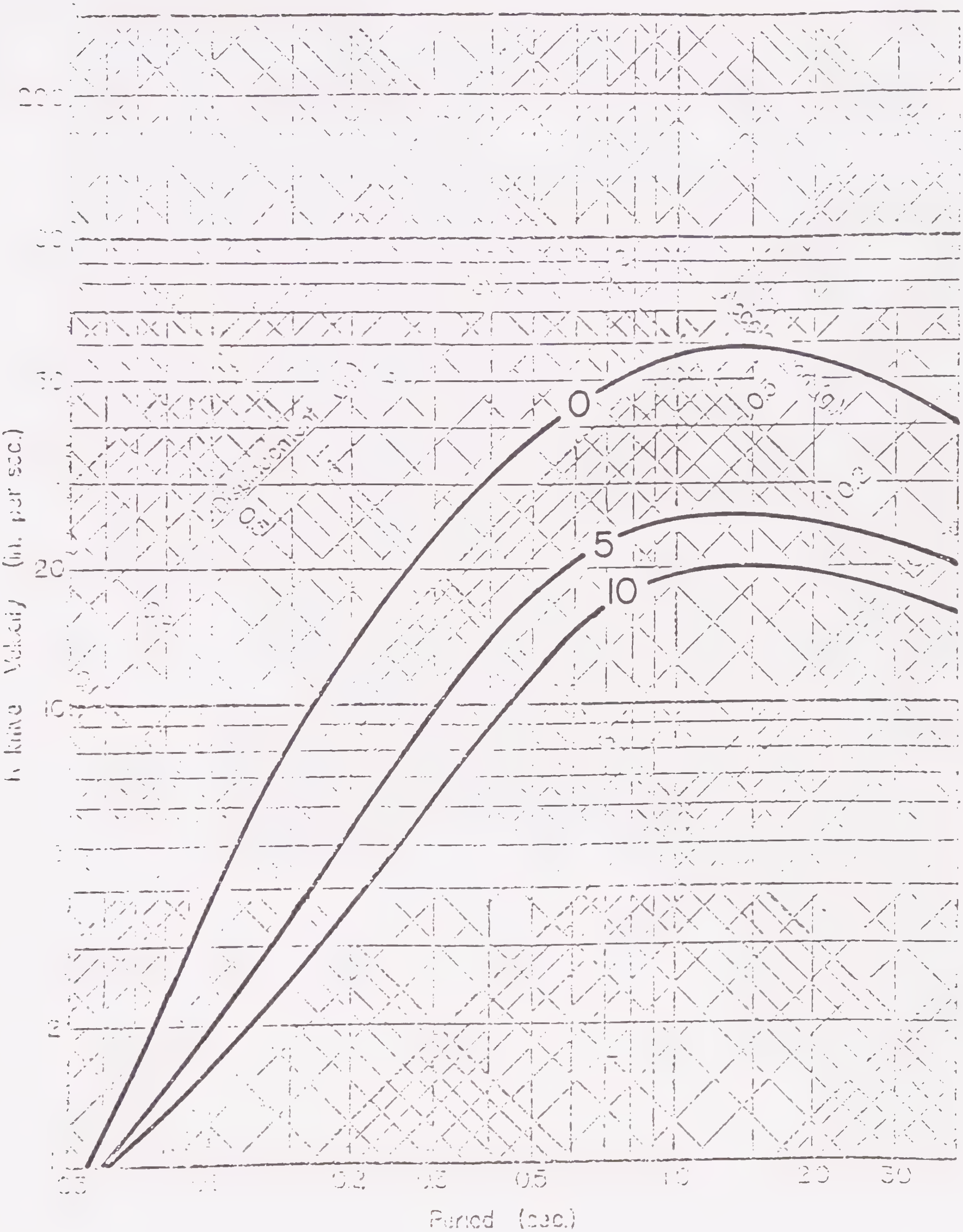


Figure 36. Response spectrum for Zone IIC for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

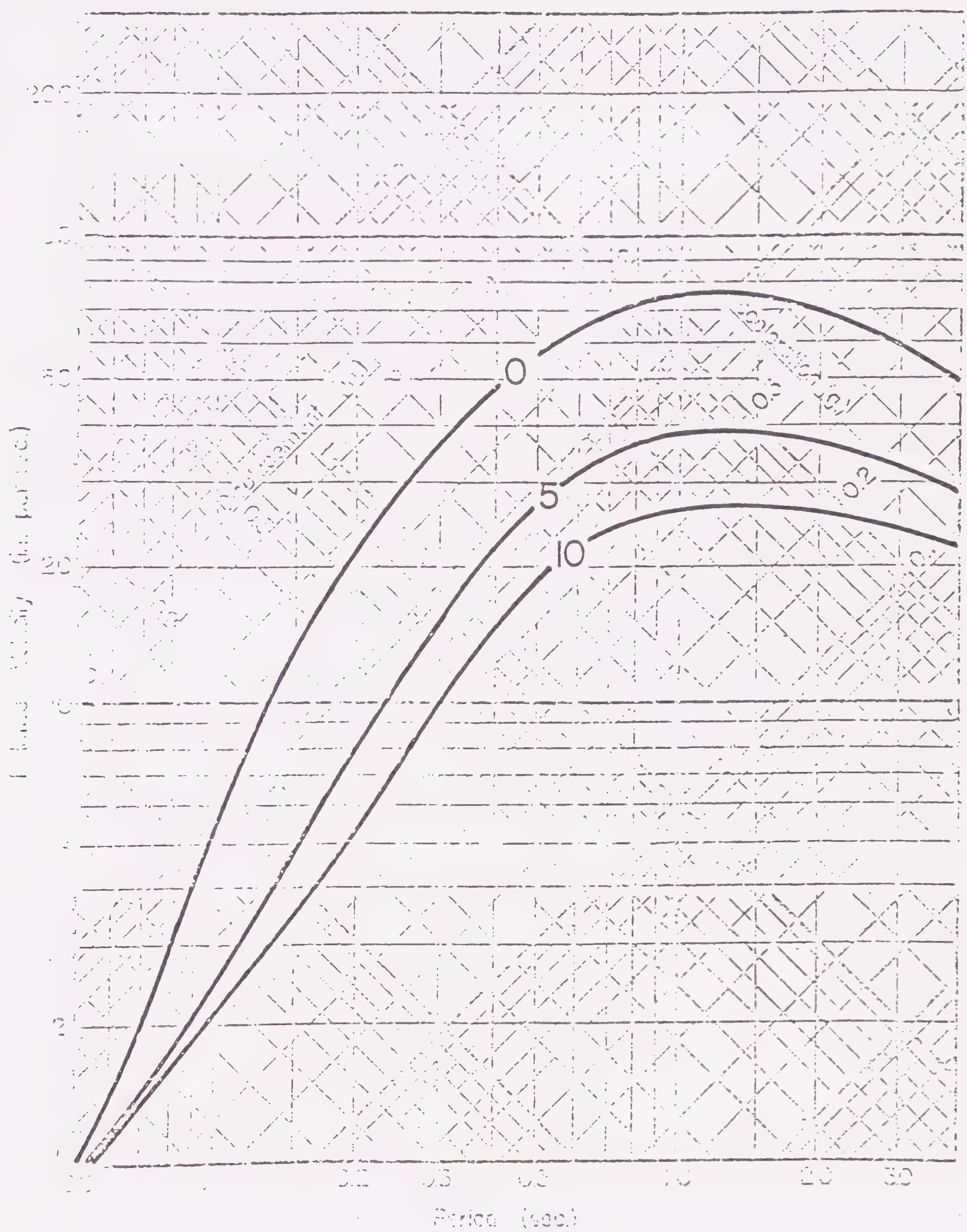


Figure 37. Response spectrum for Zone IIIA for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

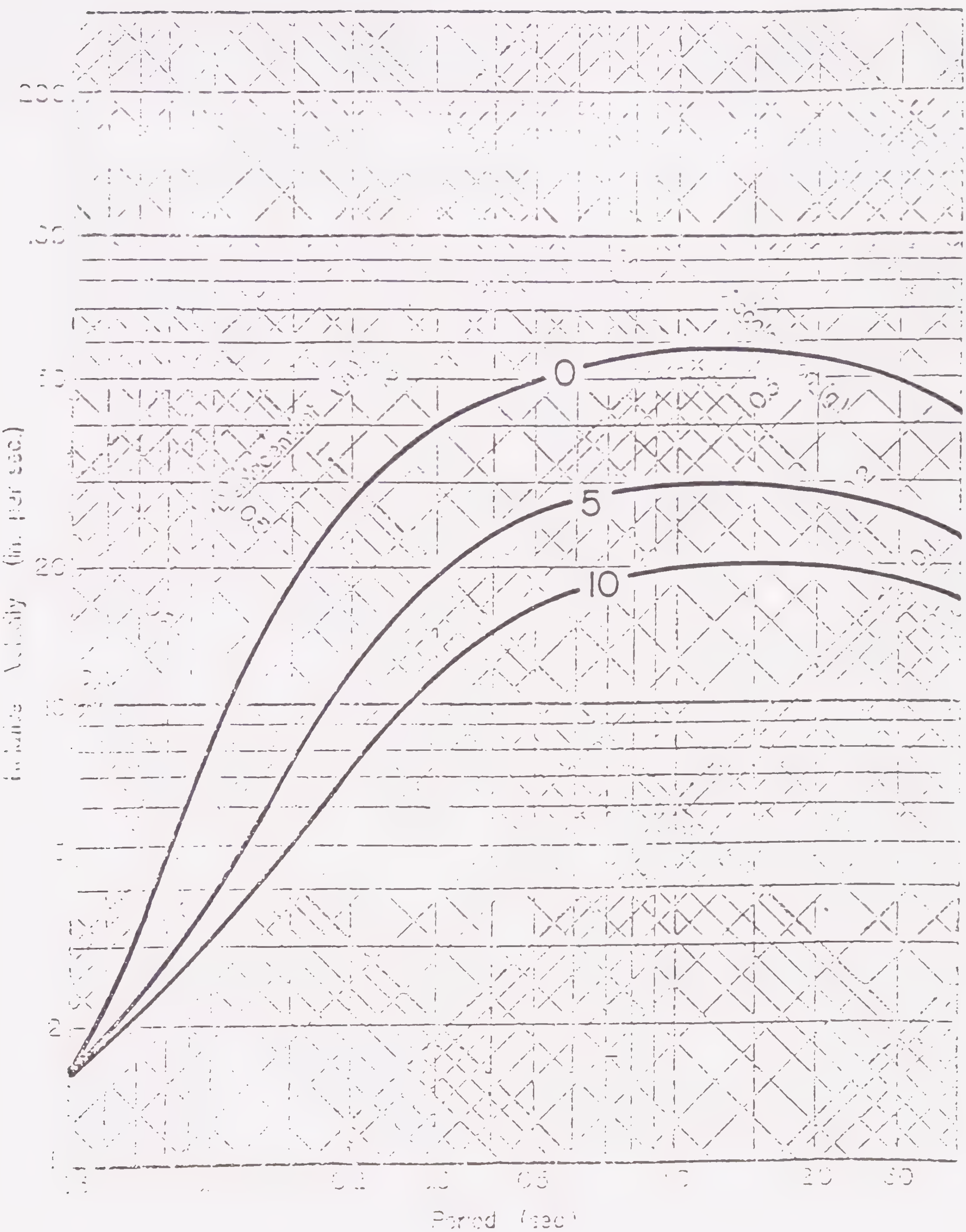


Figure 38. Response spectrum for Zone IIIB for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

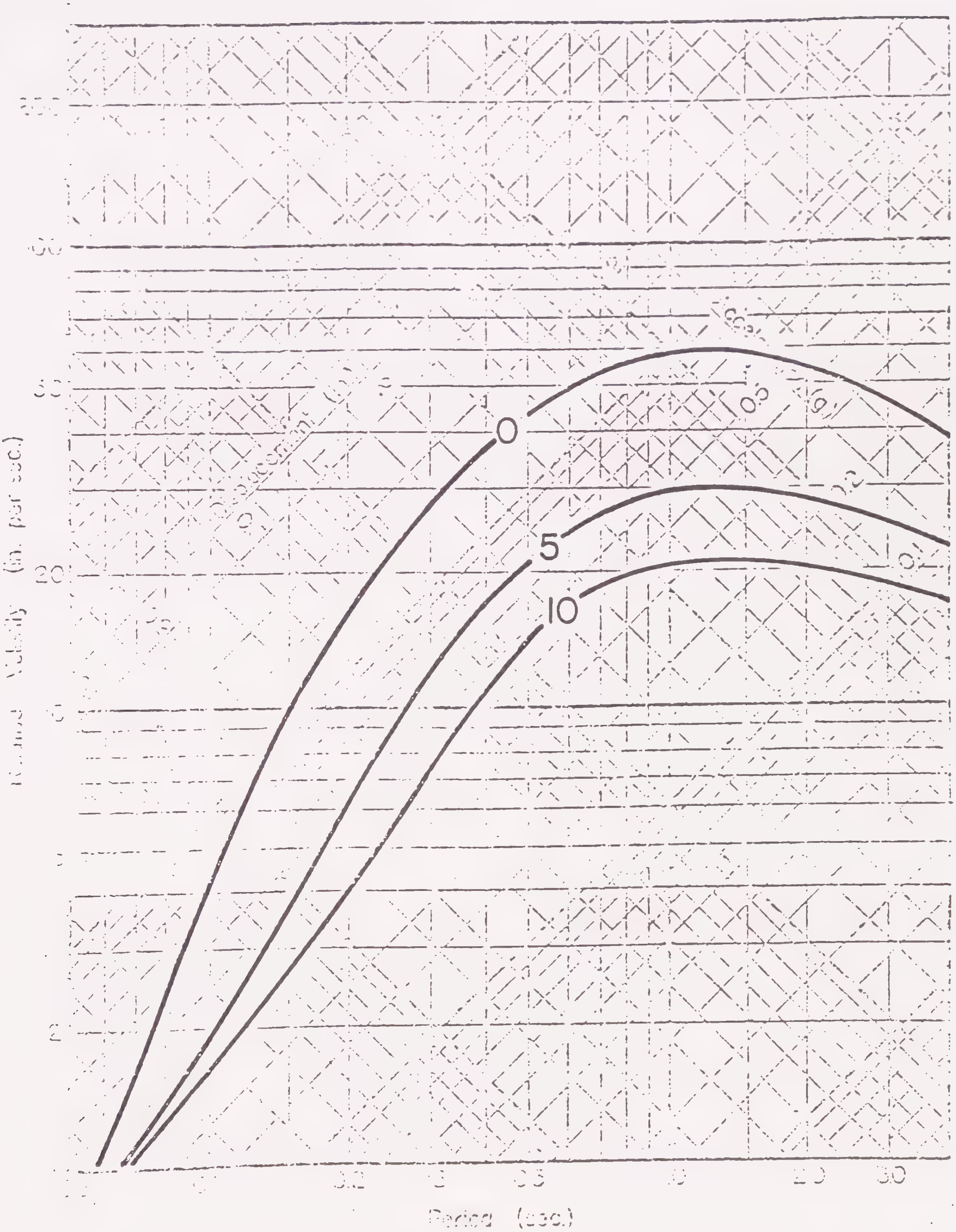


Figure 39. Response spectrum for Zone IVA for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

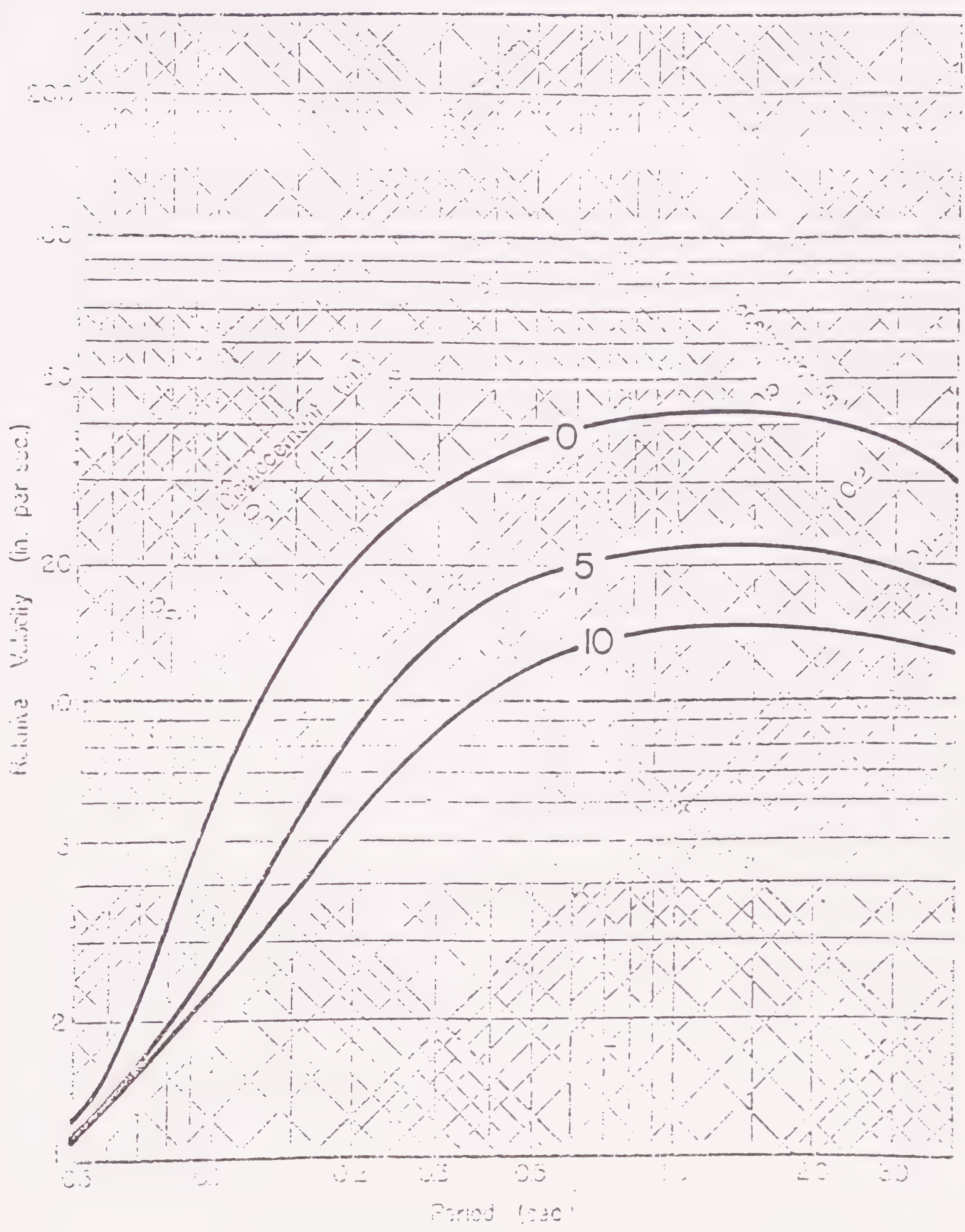


Figure 40. Response spectrum for Zone IVB for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

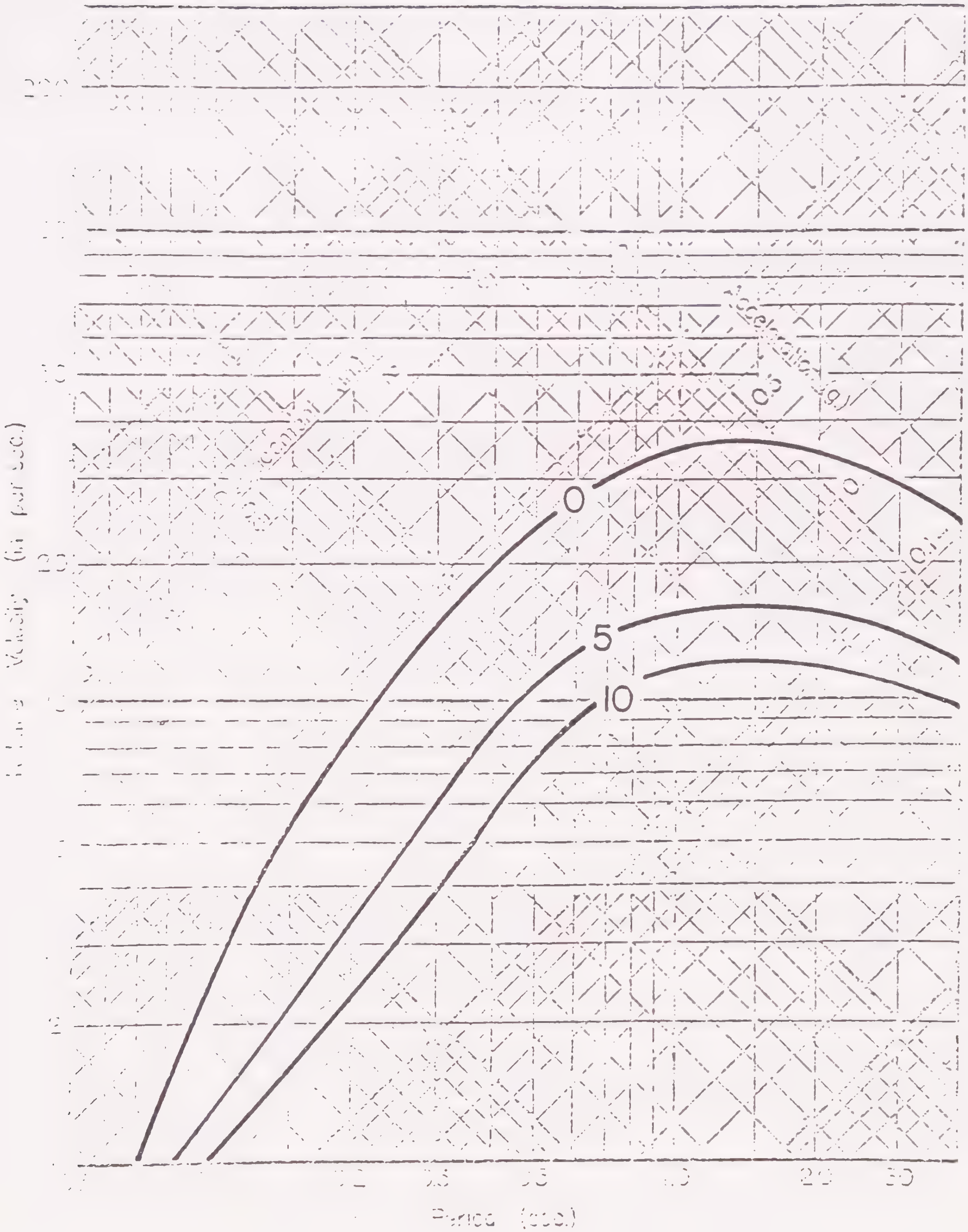


Figure 41. Response spectrum for Zone IVC for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

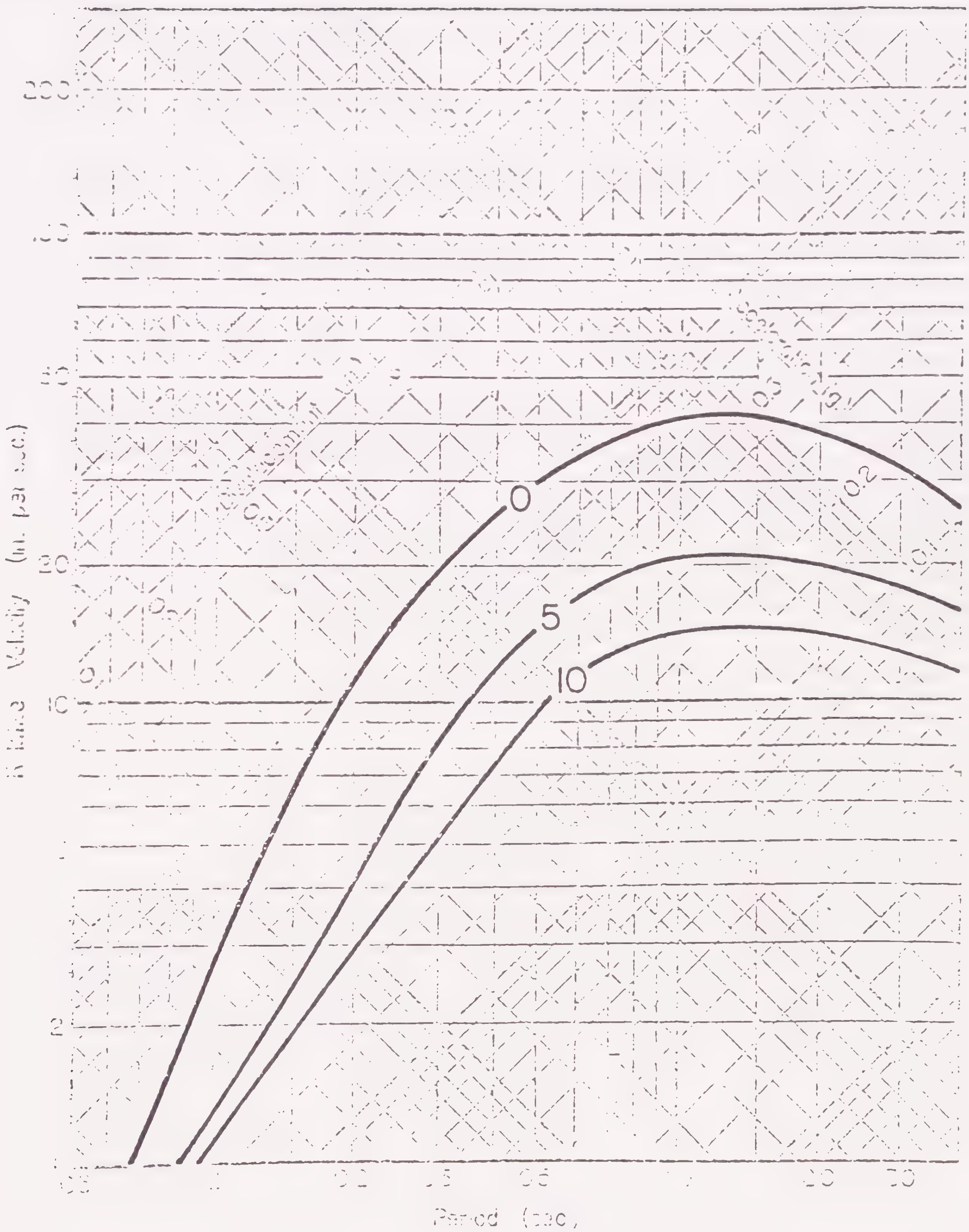


Figure 42. Response spectrum for Zone VA for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

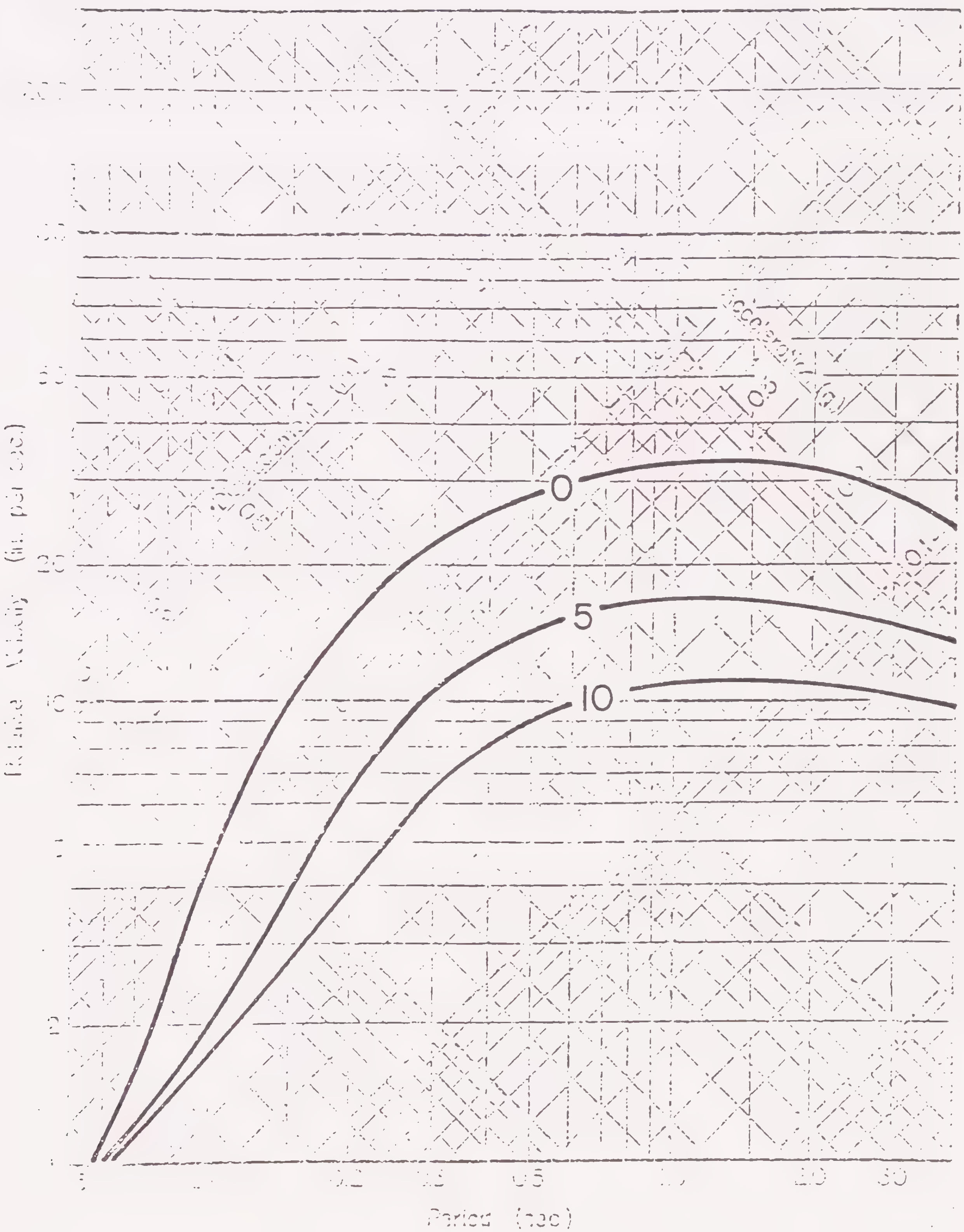


Figure 43. Response spectrum for Zone VB for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

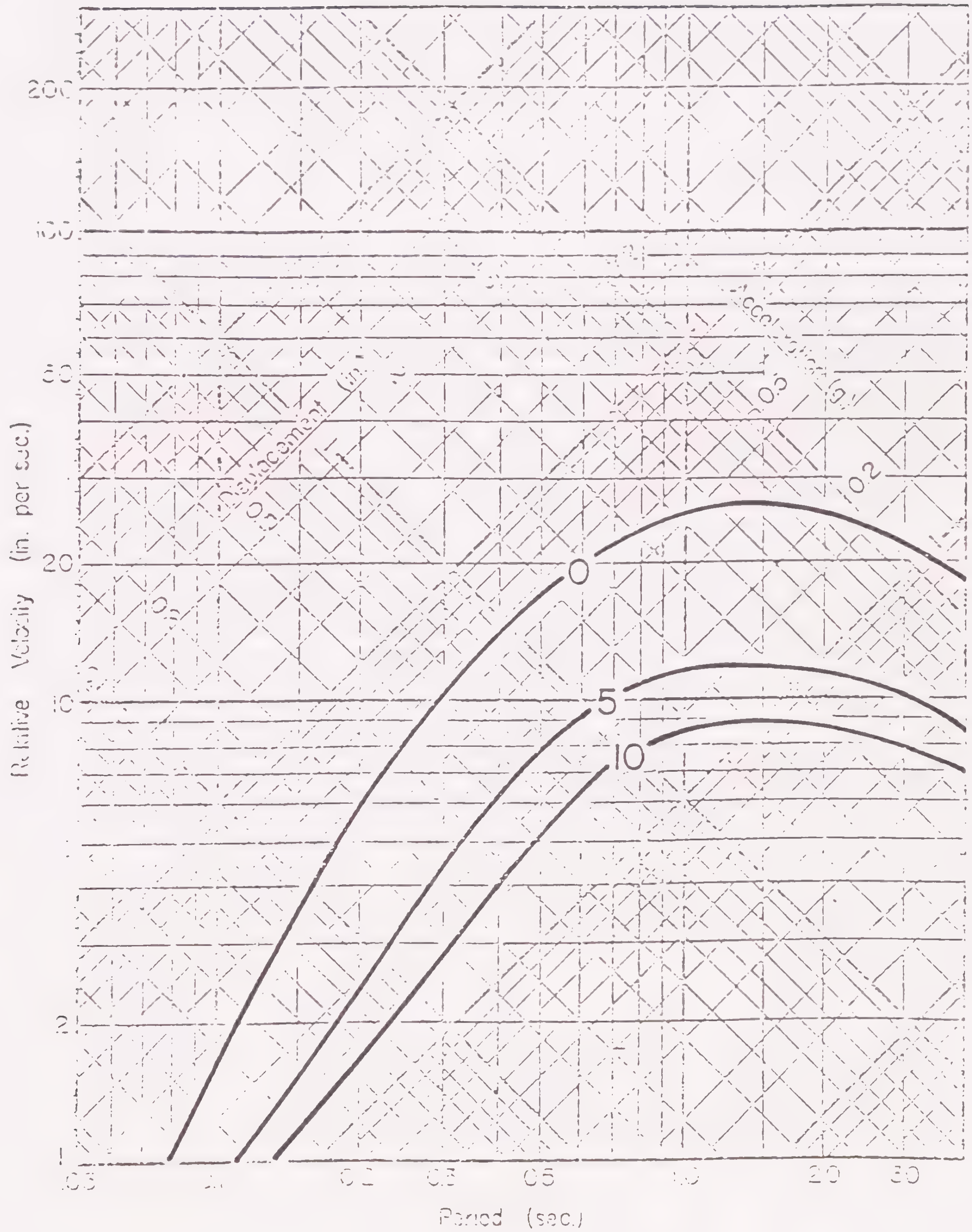


Figure 44. Response spectrum for Zone VC for magnitude 6.5 earthquake originating on the Sierra Madre fault. Curves are for 0, 5 and 10% critical damping.

In the sequence of zones, based on earthquakes expected from the Sierra Madre fault, no distinction is made between the characteristics of Zone IB (thin alluvium) and Zone IC (granite or metamorphic bedrock), and the spectrum and maximum ground acceleration as recorded at Pacoima Dam are assigned to both zones. The strict application of the methods used for the other zones would require a twofold increase in the Pacoima Dam spectrum for Zone IB. This has not been done because:

1. The Pacoima Dam motion includes very high accelerations. There is doubt as to the applicability of linear equations under such conditions.

2. The Pacoima Dam motion may include significant amplification due to the topography of the recording site.

3. The Pacoima Dam motion is the strongest ever recorded. Further amplification is questionable.

The spectra for the several zones for a magnitude 8.0 to 8.5 earthquake originating on the San Andreas fault are included as Figures 45 through 56. They have been derived using the relationships shown on Figure 18, and they are recommended as a minimum design consideration. The spectral values of the San Andreas event do not exceed those of the magnitude 6.5 event from the Sierra Madre fault in Zones I and II. They are similar or greater, depending on the period and damping of the structure under consideration, in Zones IV and V, and they are greater in some special cases in Zone III. Therefore, <u>the spectra for the magnitude 8.5 earthquake from the San Andreas fault should be considered in the design of critical or normal facilities with the appropriate spectra for earthquakes from the Sierra Madre fault as shown in Table 10</u>. The controlling design parameters may result from either earthquake depending on the natural period and damping of the structure under consideration. The San Andreas spectra are recommended for limited-occupancy facilities in all the zones because of the high probability of occurrence of this earthquake. Thus, a lower design level can be applied in Zones I, II, and generally in III, but there is very little difference in Zones IV and V (see Table 10).

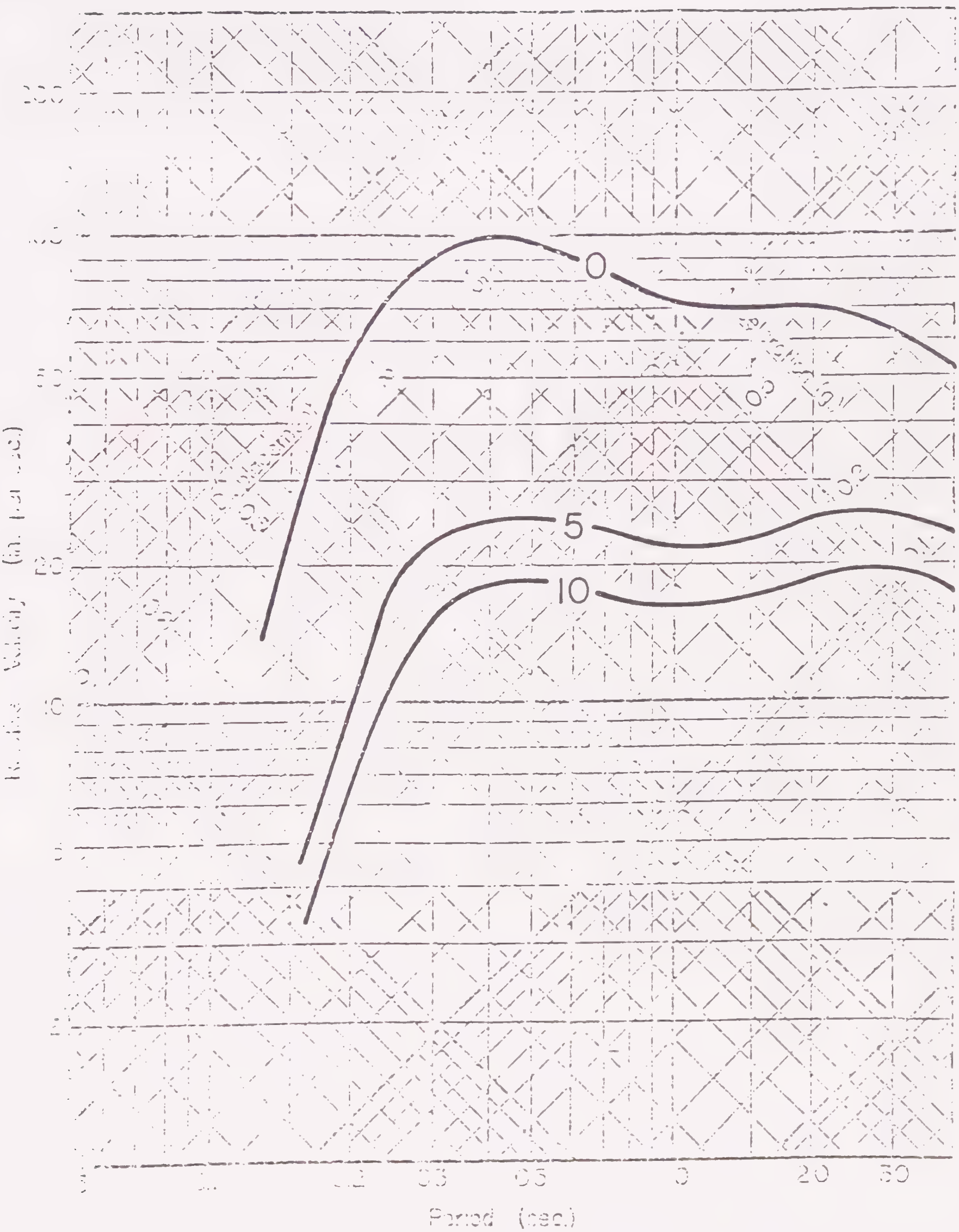


Figure 45. Response spectrum for Zones IB and IIB for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

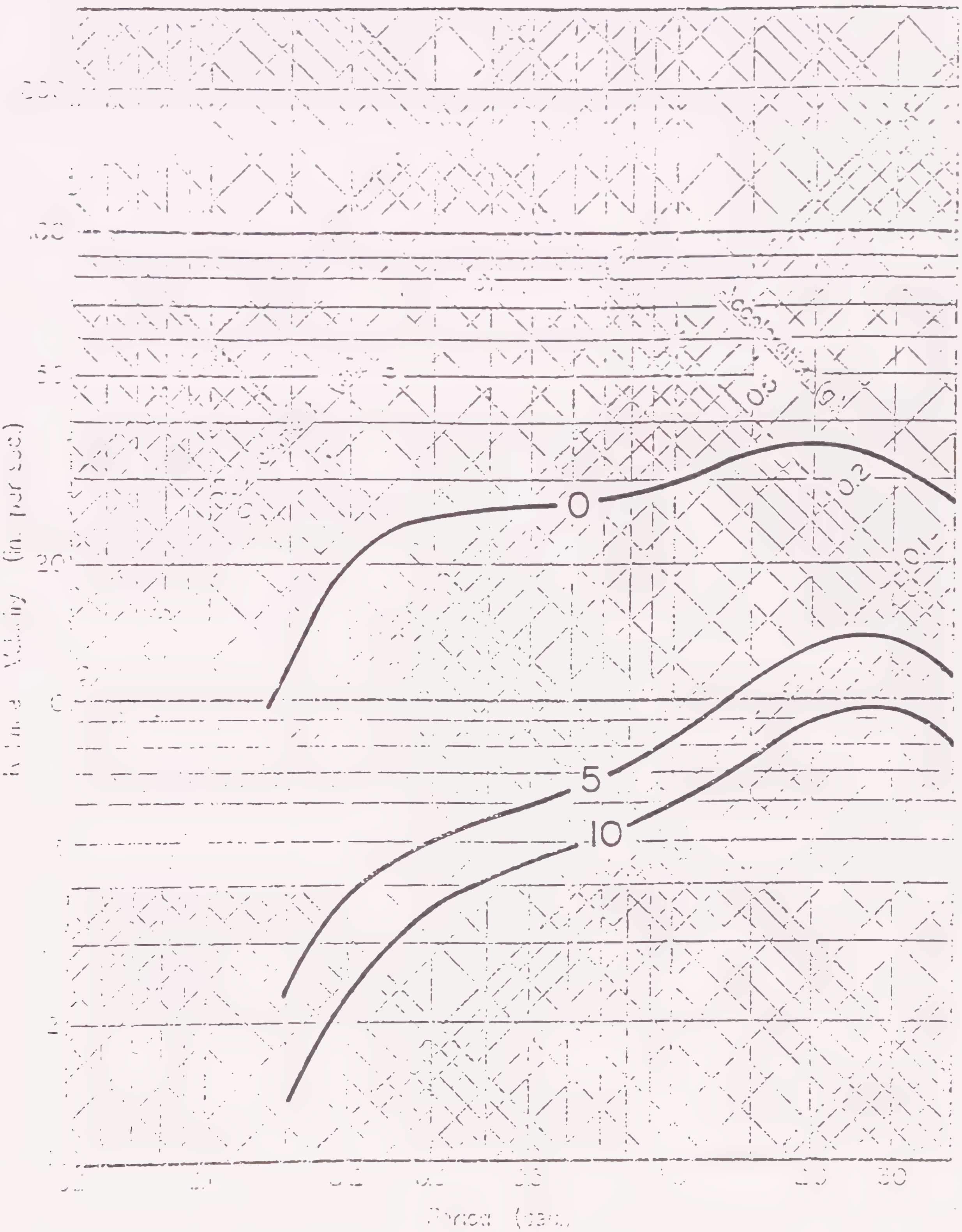


Figure 46. Response spectrum for Zone IC for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

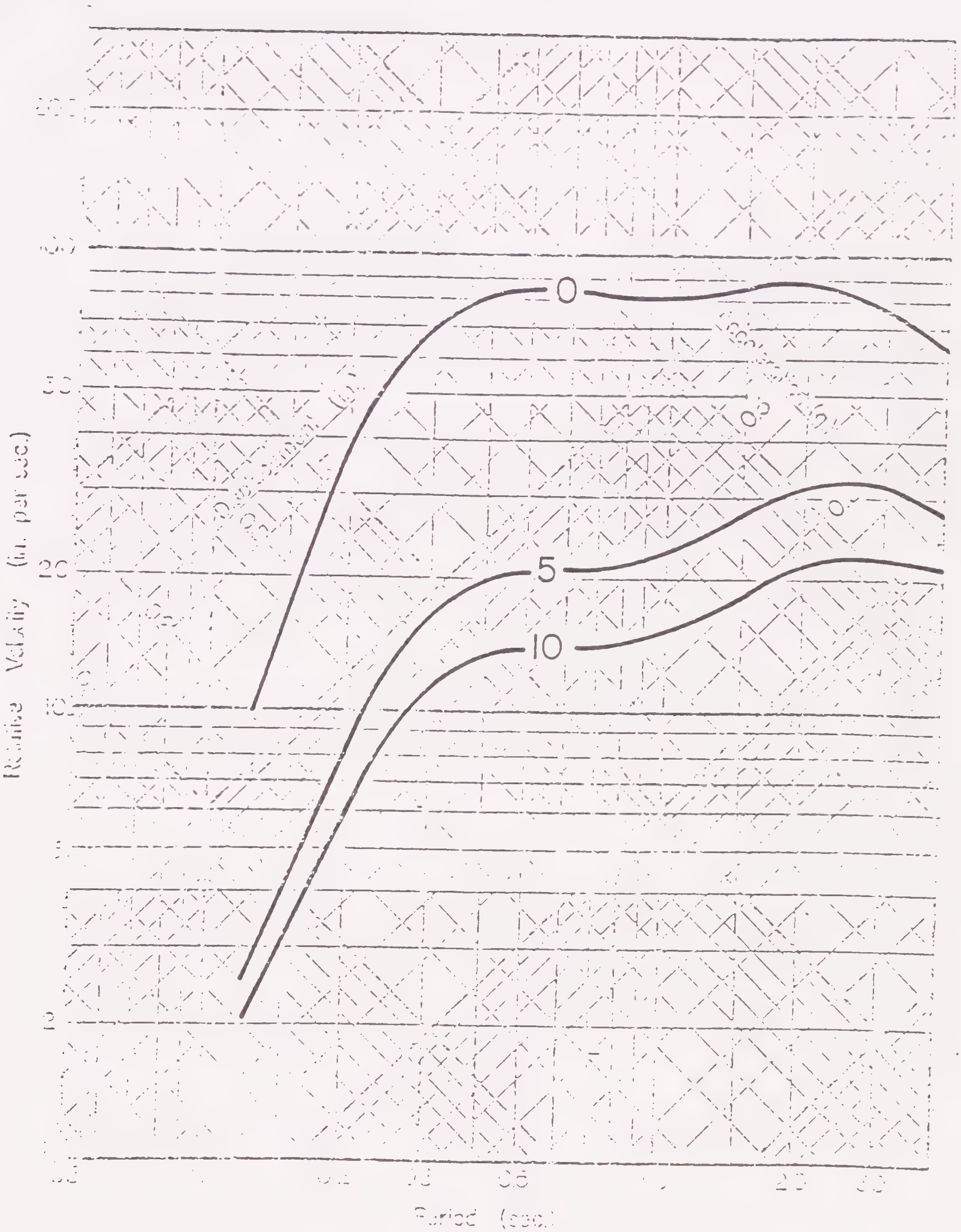


Figure 47. Response spectrum for Zone IIA for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

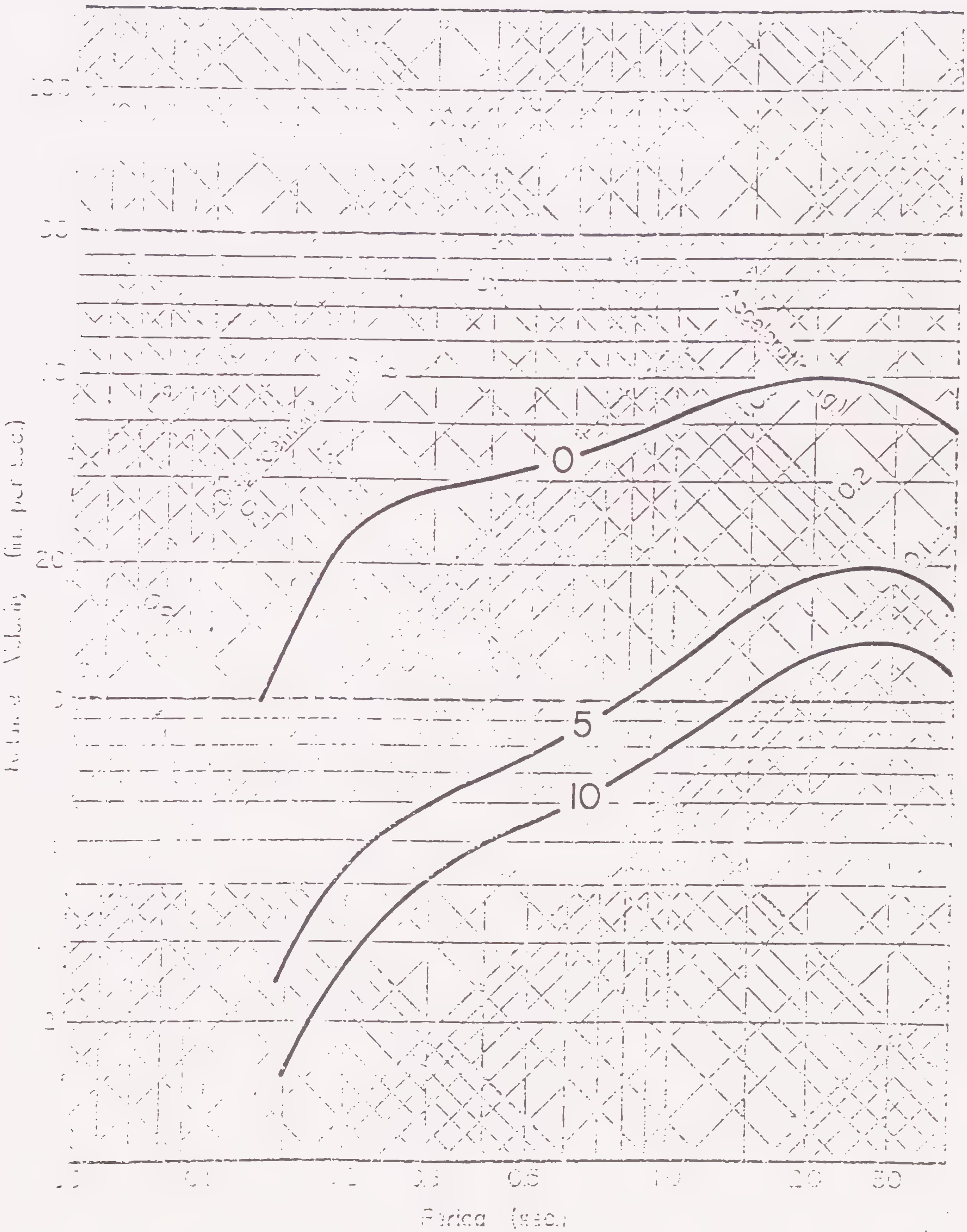


Figure 48. Response spectrum for Zone IIC for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5 and 10% critical damping.

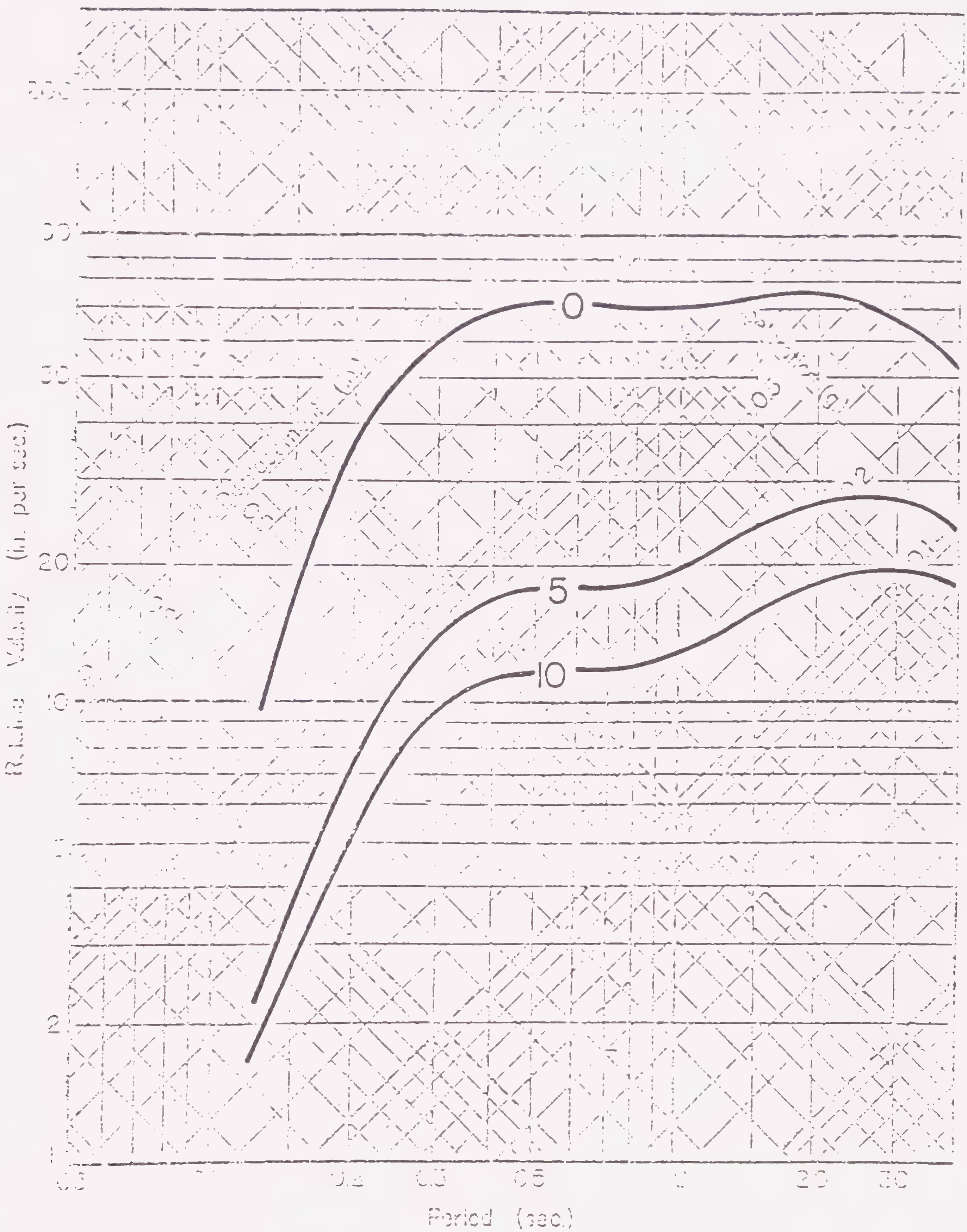


Figure 49. Response spectrum for Zone IIIA for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

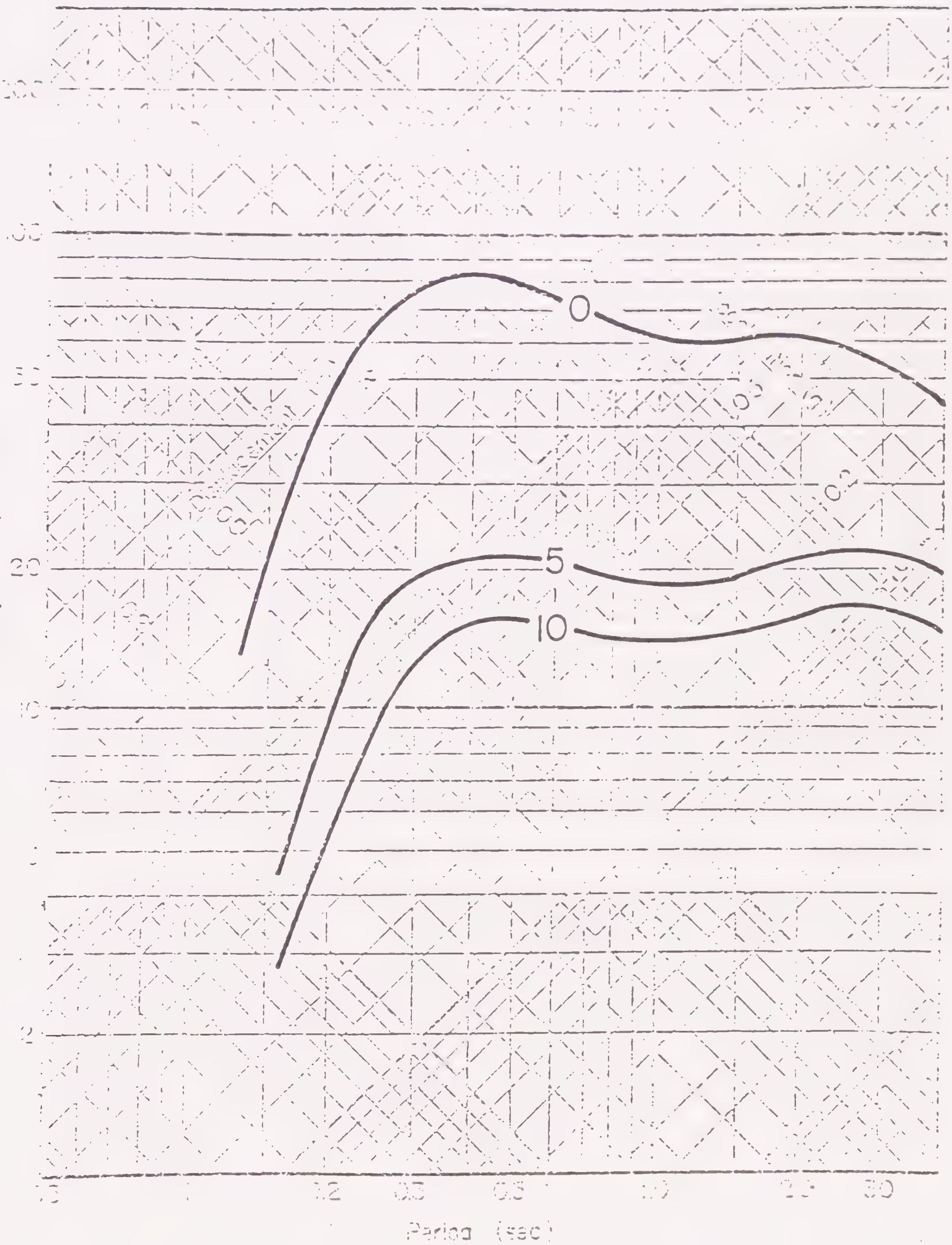


Figure 50. Response spectrum for Zone IIIB for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

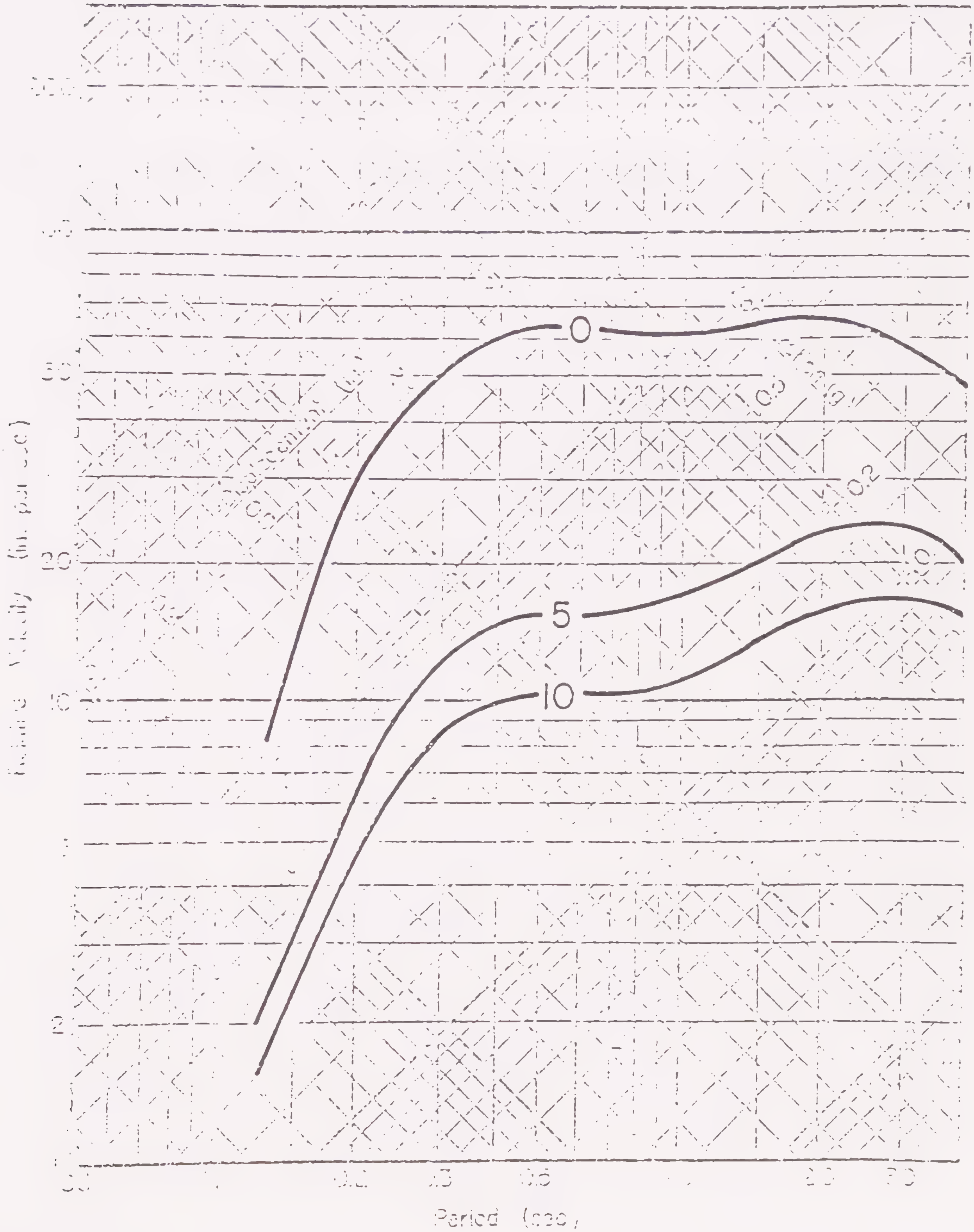


Figure 51. Response spectrum for Zone IVA for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

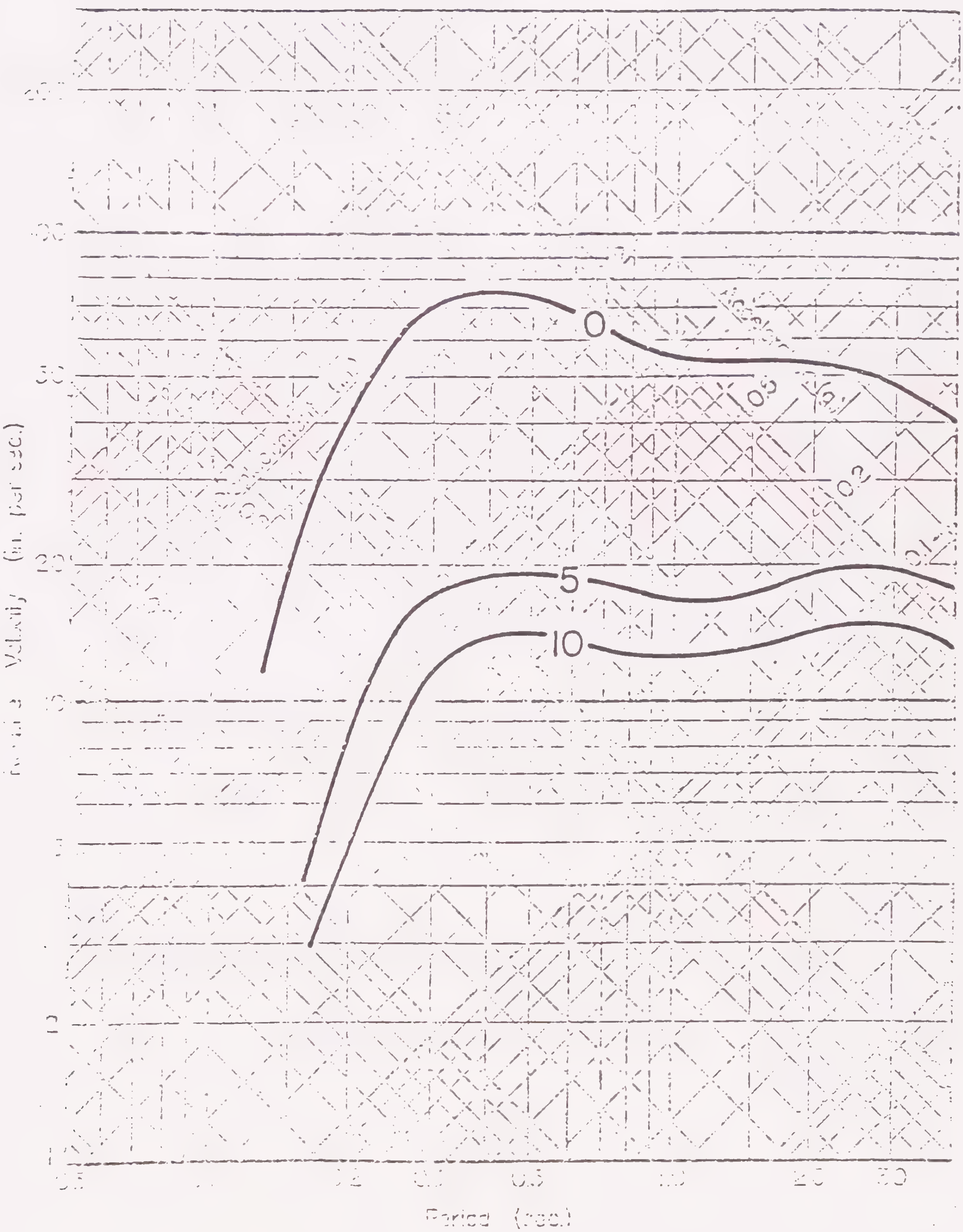


Figure 52. Response spectrum for Zone IVB for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

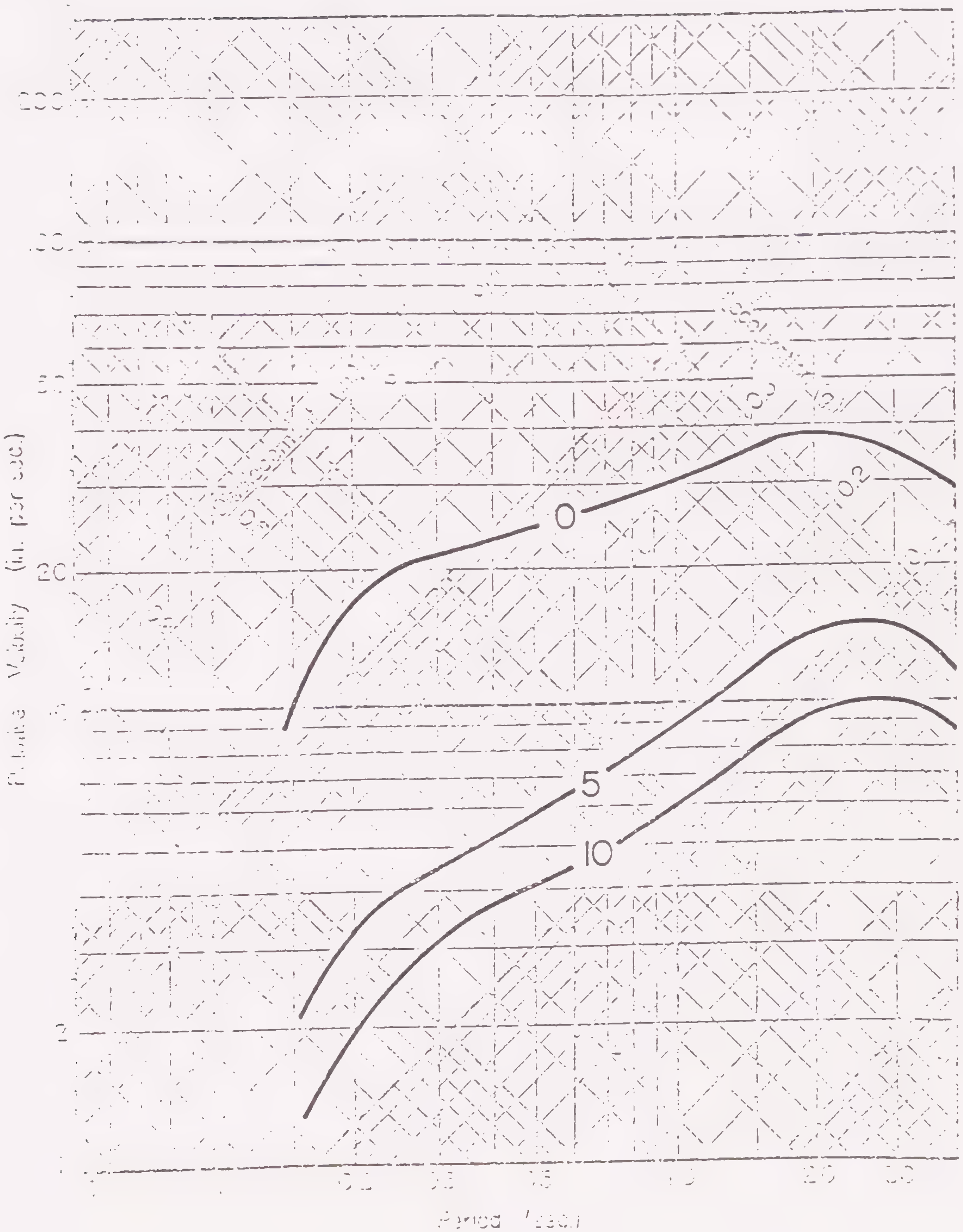


Figure 53. Response spectrum for Zone IVC for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

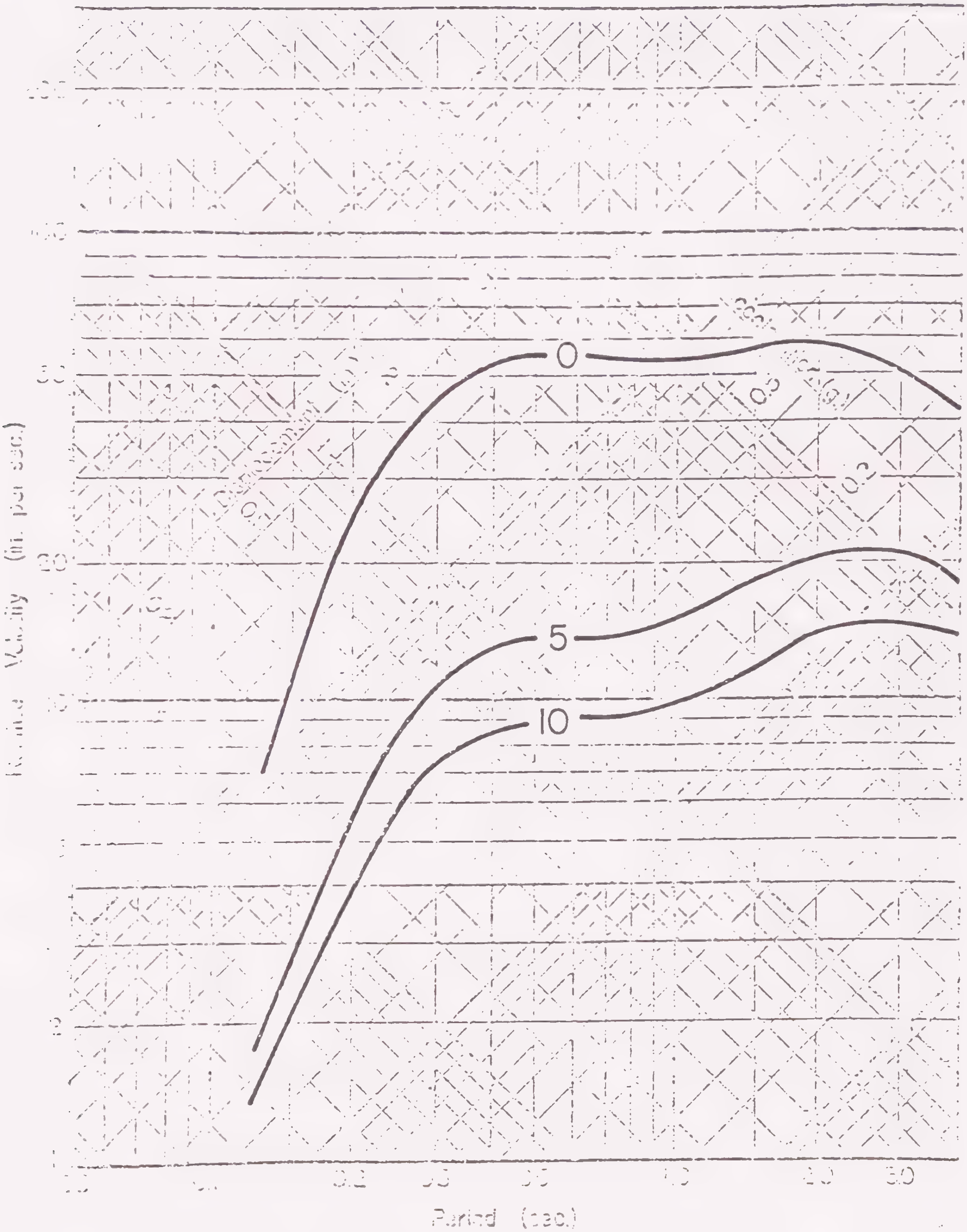


Figure 54. Response spectrum for Zone VA for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

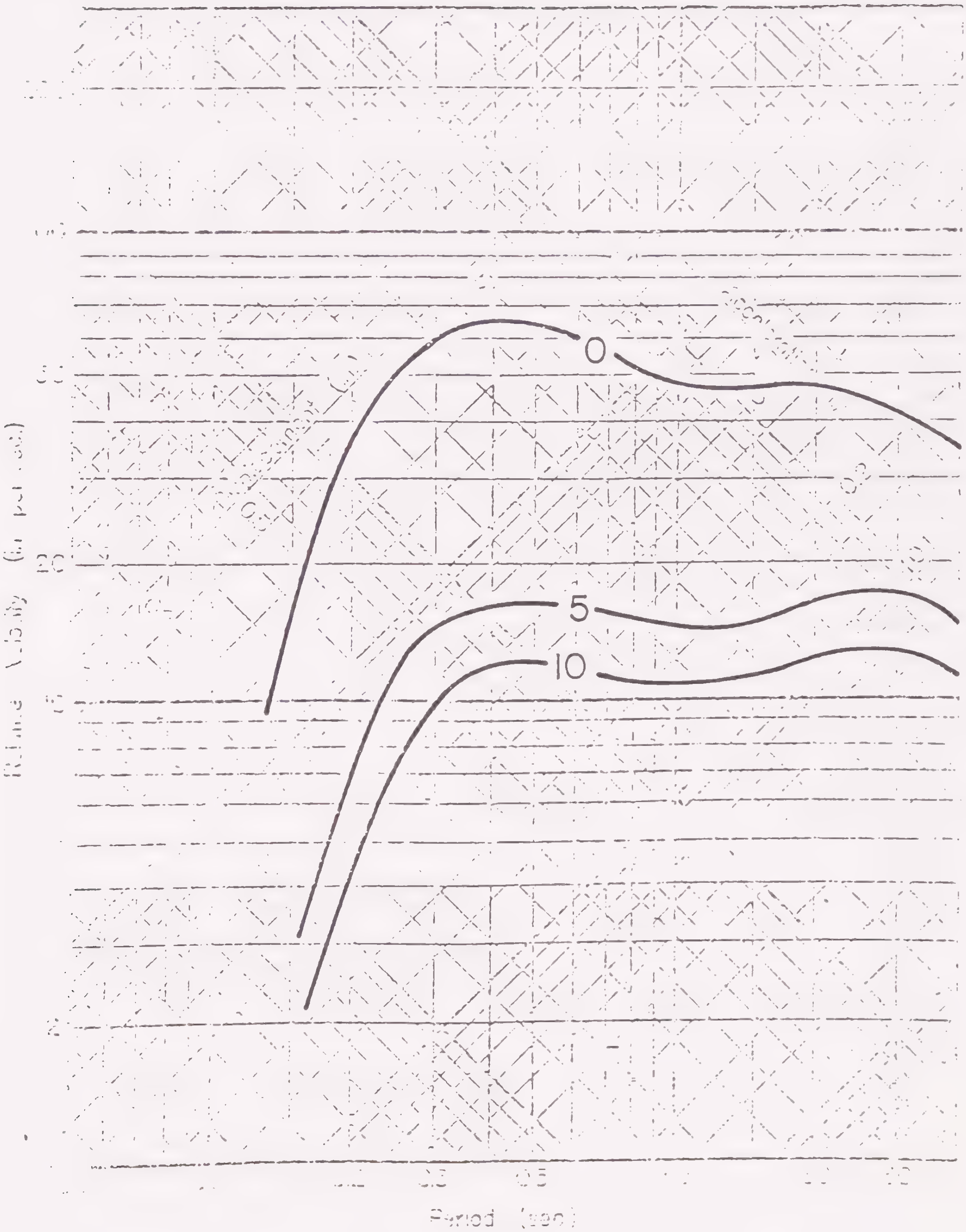


Figure 55. Response spectrum for Zone VB for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

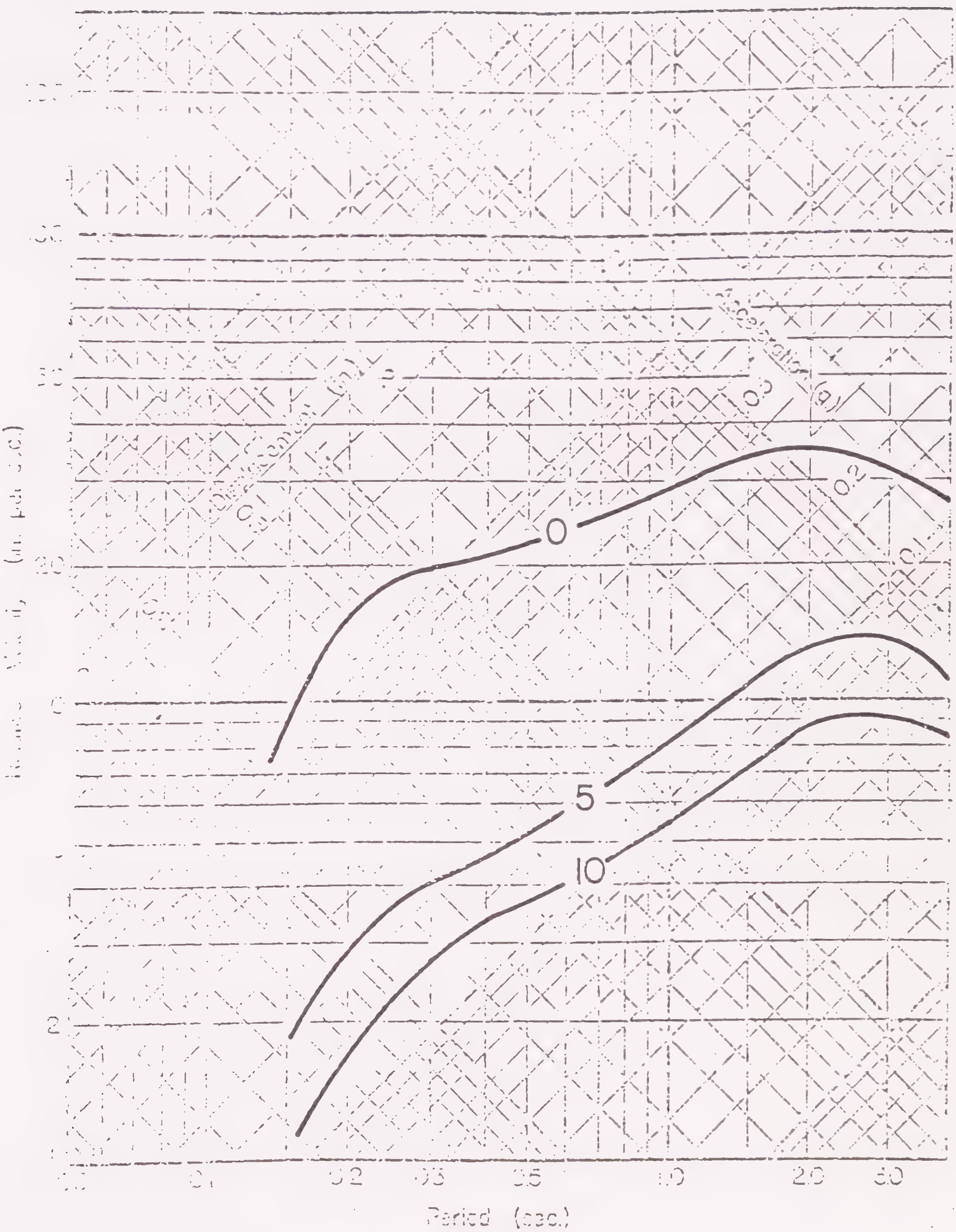


Figure 56. Response spectrum for Zone VC for magnitude 8.5 earthquake originating on the San Andreas fault. Curves are for 0, 5, and 10% critical damping.

E. SECONDARY HAZARDS

1. Settlement

Settlement may occur in poorly consolidated soils during earthquake shaking as the result of a more efficient rearrangement of the individual grains. Settlement of sufficient magnitude to cause significant structural damage is normally associated with rapidly deposited alluvial soils, or improperly founded or poorly compacted fills. The former are generally limited to active stream channels in which the risk of flooding is far greater than settlement. The problem of poorly compacted or improperly founded fills is only indirectly related to seismic hazards in that strong ground-shaking may "trigger" an already existing instability. Such instabilities are just as likely, and often are more likely, to be "triggered" by other events such as heavy rainfall. The proper solution to such problems is to require that fills be placed under the supervision of a soils engineer, and, where hillside terrain is involved, also under the supervision of an engineering geologist. In so doing, the engineer and geologist should take into account forces resulting from ground-shaking as specified herein or as developed from more detailed studies of site conditions.

Areas of concern with regard to differential settlement are located primarily along the boundary between loose, recently deposited alluvium and either bedrock or firmer alluvium. Precise location of such areas requires detailed (1"=100' or larger scale) mapping beyond the scope of this report. However, settlements along such contacts and along the cut/fill "daylight" line were common as a damaging effect in the San Fernando earthquake, and particular care should be exercised by the soils engineer in evaluating a site where this type of condition is present.

2. Liquefaction

Liquefaction involves a sudden loss in strength of a saturated, cohesionless soil (predominantly sand) which is caused by shock or strain, such as an earthquake, and results in temporary transformation of the soil to a fluid mass. If the liquefying layer is near the surface the effects are much like that of quicksand on any structure located on it. If the layer is in the subsurface, it may provide a sliding surface for the material above it. Liquefaction typically occurs in areas where the groundwater is less than 30 feet from the surface, and where the soils are composed predominantly of poorly consolidated fine sand.

As shown on the seismic hazards map (Plate I), most of the City of Industry falls within the zone of potential liquefaction. This zone also includes parts of the adjoining cities of Walnut, La Puente, El Monte, Pico Rivera, Whittier, and all of South El Monte. The designation does not mean that the entire area shown will, in fact, liquefy during prolonged seismic shaking, because details of soil types and grain sizes would have to be determined before a more detailed map could be drawn. Also, water table fluctuations occur which would make the boundary of the zone vary from season to season.

A small part of the City of Azusa would lie within the high water line of Santa Fe reservoir when water is running over the spillway. This area may be inundated occasionally, but it is doubtful if liquefaction would occur here because the sands and gravels are too coarse-grained to liquefy. This would apply to the entire San Gabriel River floodplain north of the dam, even though seasonally the water table is at or very near the surface, as in the spreading ground area near the mouth of the canyon.

Serious ground lurching and possible liquefaction was reported during the 1857 Ft. Tejon earthquake at Temple's Ranch (Barrows, 1857), near the San Gabriel River in the present City of El Monte. Today, both the San Gabriel and Rio Hondo Rivers from El Monte to below the Whittier Narrows Dam are areas of rising groundwater. This implies that the entire Whittier Narrows basin, including parts of the City of Industry, is especially vulnerable to liquefaction.

In those areas in which liquefaction is considered a potential hazard, evaluation of this problem by the soils engineer at the time development is proposed is important. This evaluation would be based on detailed data on relative compaction obtained during the site investigation and on the levels of ground shaking developed herein for the various zones. The charts shown on Figure 57 show the interrelationships between ground shaking (maximum ground acceleration), relative density, depth to the water table, and the probability of liquefaction.

3. Landslides and Slope Stability

a. Types of Landslides

Landslides represent only one step in the continuous, natural erosion process. They demonstrate, in a dramatic way, the tendency of natural processes to seek a condition of equilibrium. The steep slopes of mountainous and hillside terrain are not in a state of equilibrium, and various erosional processes act on them to gradually reduce them to near sea level. Landsliding is an important agent in this cycle.

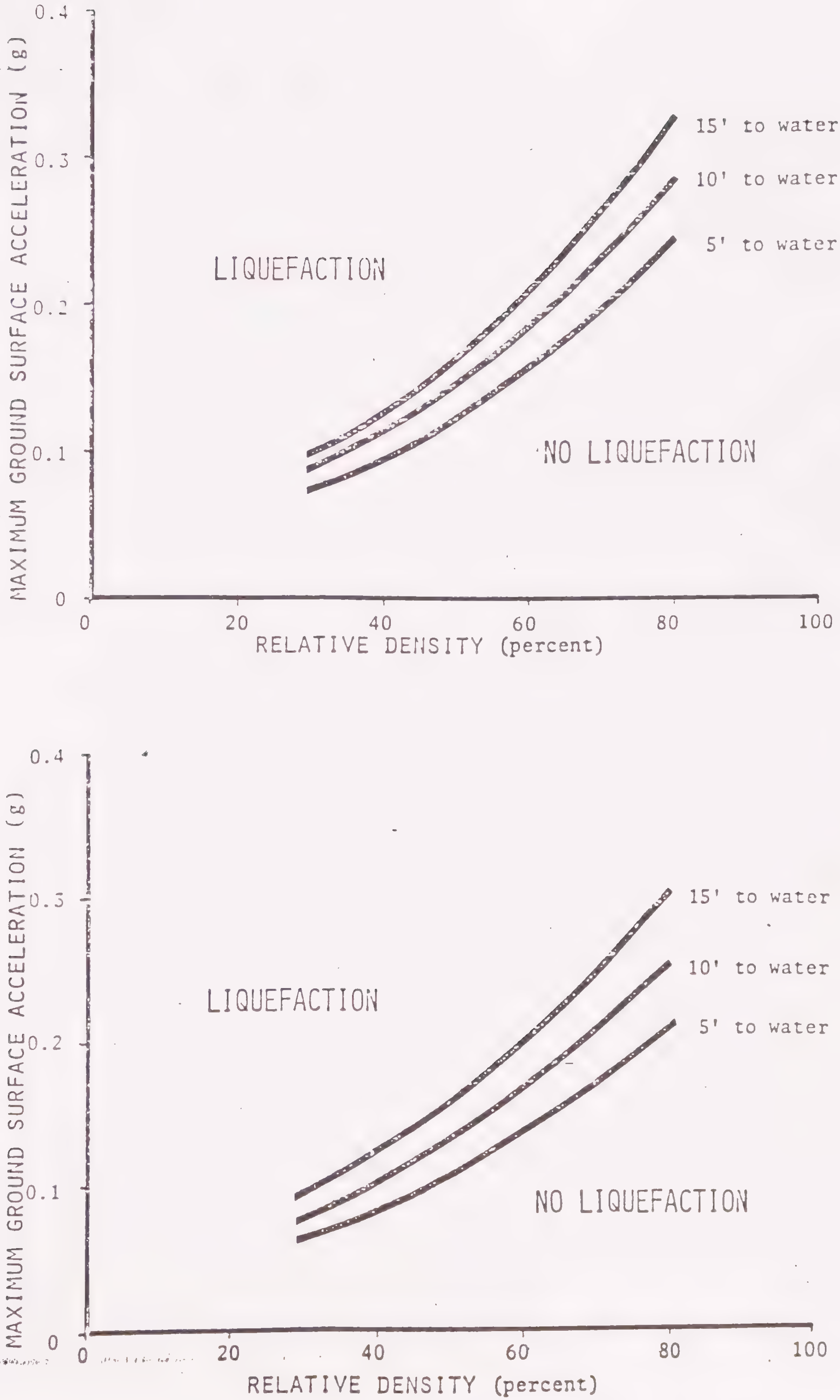


Figure 57. Liquefaction potential during a magnitude 6.5-7.0 earthquake (top) and a magnitude 8.0-8.5 earthquake (bottom).

Several types of landslides commonly encountered include:

1. Block glides (Figure 58) - These are the largest, most impressive type of slide. The basal failure plane is controlled by planar zones of weakness such as bedding planes, joint planes, or formational contacts. Block glides typically occur in layered rocks of sedimentary or metamorphic origin where lateral support is removed by stream erosion.

2. Arcuate failures (Figure 59) - Arcuate failures are common in massive, unstructured material with relatively little resistance to shearing. These materials include thick sections of clayey soil, and poorly compacted artificial fills. The zone of failure typically describes an arc rather than a plane, and the movement of the mass is partly rotational. Small arcuate failures, called slumps, are common along steep-banked streams, where the stream has cut through an existing soil zone.

3. Mudflows (Figure 60) - Mudflows involve very rapid downslope movement of saturated soil, sub-soil, and weathered bedrock. They originate in hillside areas where the soil horizon is well developed, but the soil has poor drainage characteristics. Large mudflows may have the energy to uproot trees and to carry along boulders several feet in diameter. Because of the speed with which they move, mudflows can be quite destructive, especially along the bottoms and at the mouths of canyons.

4. Rockfalls (Figure 61) - This phenomenon, much like an avalanche of loose rock, cascades down a steep slope, disturbing more material as it passes, becoming more widespread, until it reaches the bottom of the slope. The large talus slopes common in the San Gabriel Mountains are the debris deposited from rock falls. They are prevalent where natural weathering produces angular fragments of material with little soil cover.

b. Relationships of Earthquakes to Landslides

Landslides should be considered a basic geologic hazard rather than one having an unusual association with earthquakes. The shaking of an earthquake only provides the triggering force to initiate downslope movement of a previously unstable earth-mass. The prime factor is the unstable condition itself. Movement could just as easily be triggered by heavy rains, or by grading on a construction project.

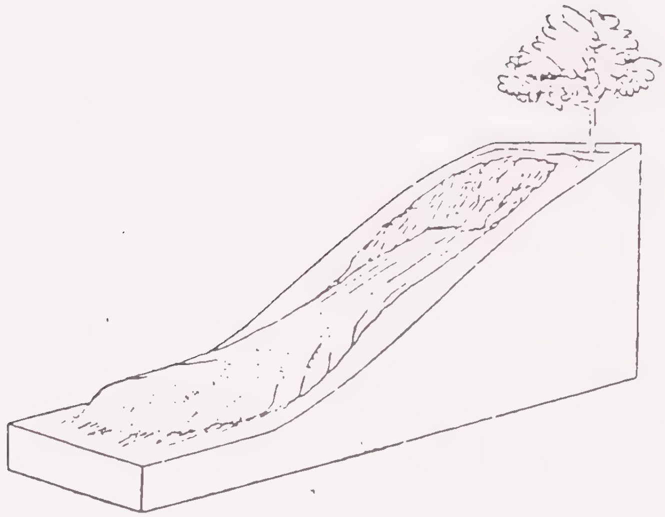


Figure 58. Mudflow of saturated soil and weathered bedrock (From USGS MF-338.)

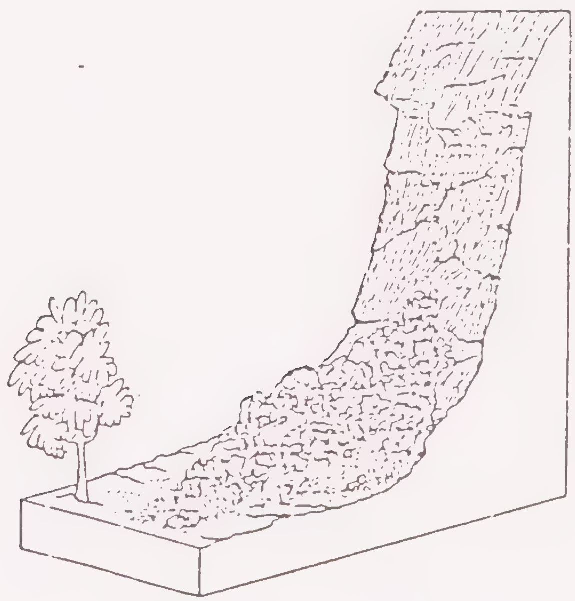


Figure 59. Rockfall involving a cascade of weathered bedrock down a steep slope (From USGS MF-338.)

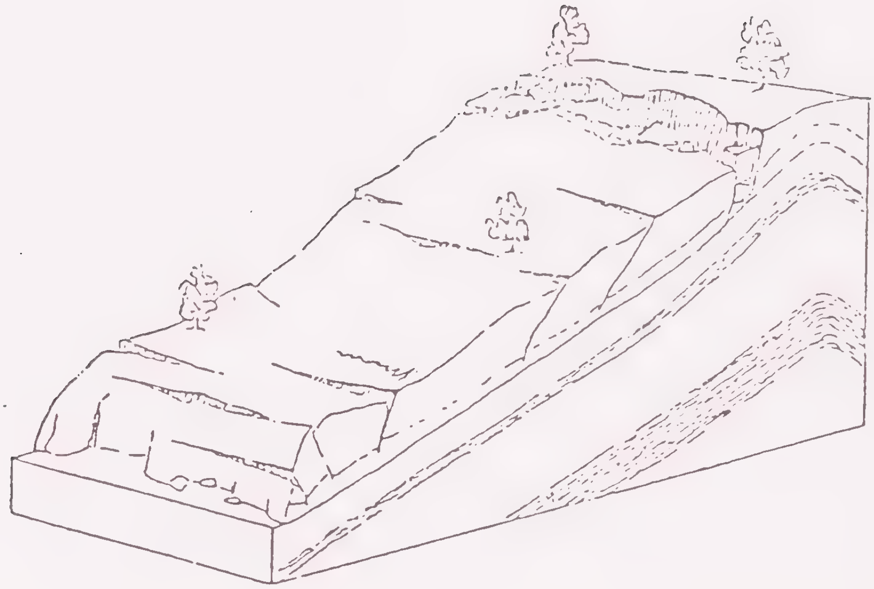


Figure 60. Block-glide landslide which has failed along an unsupported bedding plane.

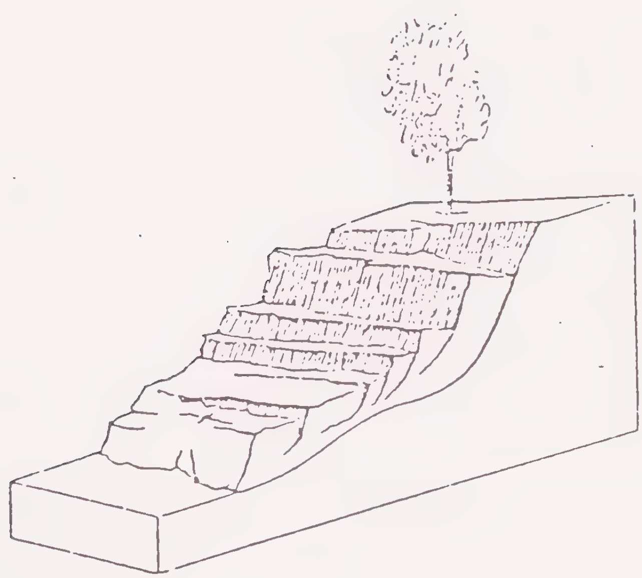


Figure 61. Slump occurring in unstructured soil along an accurate failure path. (From USGS MF-338.)

c. Appraisal of Slope Stability

Appraisal of slope stability is based on a dual process of showing natural landslides where they have been mapped and are known to exist, and also a slope stability rating based on rock type and steepness of slope. The latter is necessary for two reasons. First, data on landslides is incomplete, and many other natural landslides may be present besides those shown on Plate I. Also, natural landslides are only part of the problem. Development of a site may significantly alter the geometric relationships between topography and planes of rock weakness such as bedding, jointing or fault planes. In such areas, it is the tendency of certain types of rocks to develop landslides that is the important factor in evaluating the relationship between slope stability and land use.

Categories in the slope stability rating, as shown on Plate I, are based on the distribution of known landslides and the physical characteristics of mapped geologic units as follows:

Category	Description
0	Risk very low to nil. Includes primarily the flatter areas of the San Gabriel Valley. Instabilities limited primarily to local bank failures along streams.
1	Low risk. Hill areas underlain primarily by relatively resistent sandstone or conglomerate. Formations include the middle Puente of the San Jose Hills, and the Soquel and Sycamore Canyon members of the Puente in the Puente Hills.
2	Moderate risk. Hill areas underlain primarily by siltstone or mixed siltstone and sandstone. Formations include the Upper Puente and Pico in the San Jose Hills, and the Yorba Member of the Puente in the Puente Hills. In the San Gabriel Mountains, the south-facing, moderately steep slopes north of Azusa are included in this category.
3	High risk. Hill areas underlain by relatively weak rocks with a high clay content. Formations include the Lower Puente in the San Jose Hills and the La Vida Member of the Puente in the Puente Hills. In the San Gabriel Mountains, the steep slopes with a high percentage of landslides are included in this category.

The above slope stability rating does not include the effects of mud or debris flow. This type of instability results from the accumulation of rock, soil, and debris on steep slopes and in the canyon bottoms. Heavy rains, particularly after a fire, cause this material to flow downslope, either directly onto homes in the hillsides, or out of the canyons and into developments at the base of hills. As such, this type of instability is more directly related to heavy rain and fire than to seismic triggering or an inherent geologic instability. Also the extent of accumulations of material suitable for the formation of a mud or debris flow tends to vary considerably over short distances and also with time depending on the modifications of an area during development. Consequently, this aspect of slope stability must be handled on a site-by-site basis at the time of development by including the consideration of mud and debris flow hazards in site evaluations in hillside and near-hillside areas.

F. TSUNAMIS AND SEICHES

Tsunamis, commonly called "tidal waves", are caused by fault movement on the sea floor, and commonly affect lowlying coastal areas. They will have no effect on the study area.

Seiches are standing waves produced in a body of water by winds, atmospheric changes, the passage of earthquake waves, etc. Studies of true seismic seiches are limited, but that by Mc Garr and Vorhis (1968) of seiches induced by the Alaska earthquake of 1964 indicates that the largest recorded wave heights (double amplitude) did not exceed 1.2 feet. Since this is less than wave heights that would be expected from wind-induced waves, true seiches are not considered as constituting a significant hazard in the study area.

It should be noted, however, that considerable confusion exists as to the application of the term seiche. The definition included herein (see Glossary of terms), limits a true seismic seiche to standing waves set-up by the passage of seismic waves from an earthquake. Traveling waves set-up by landsliding into or within a lake or reservoir, or those induced by the tilting of the water body, are not true seismic seiches. Dramatic examples of damage attributed at least in part to seiching at Hebgen Lake in Montana in 1959 (Christopherson, 1962) or at Kenai Lake in Alaska in 1964 (McCulloch, 1966) are more likely the results of traveling waves (or reflected traveling waves) set-up by landsliding or the tilting of the reservoir bottom.

The principal hazard to the study from landslide or tilt induced seiches would be at Morris or San Gabriel Dams north of Azusa. The landslides adjacent to Morris are not of sufficiently large volume to constitute a significant risk, but tilting of the area north of the Sierra Madre fault may well accompany movement along this fault. San Gabriel reservoir is used for flood control and the risk of it being full at the time of a major earthquake is extremely remote. Morris, on the other hand, is used for water storage, and is near-full a higher percentage of the time. A complete analysis of this problem is very complex and beyond the scope of this report, but the owners of this facility should be advised of the results of this investigation so they may evaluate its safety.

III. CONCLUSIONS AND RECOMMENDATIONS

1. On the basis of available information, the Sierra Madre fault zone and the two adjacent faults, the Duarte and Lower Duarte faults, are considered active.

2. The Phase II program of the Division of Mines and Geology (1974-1975) for the delineation of Special Studies Zones are required by the Alquist-Priolo Act includes the "Sierra Madre-Santa Susana-Cucamonga" fault. Cities located along the Sierra Madre fault should expect the establishment of such a zone before the end of 1975.

3. The primary seismic hazard in the study area is strong to severe ground shaking generated by movement of the Sierra Madre, San Andreas or Whittier faults.

4. Information bearing on the risk of occurrence of various magnitude earthquakes on those three faults is developed in the text of the report. Based on these risk levels the following are recommended for consideration in the design of facilities as follows:

	Magnitude of Earthquake		
Use	Sierra Madre Fault	San Andreas Fault	Whittier Fault
Limited Occupancy	6.5	8.5	4.5
Normal Occupancy	6.5	8.5	5.2
Critical Facilities	7.5	8.5	6.0

5. Microzonation of the study area is based on the distance to the earthquake-generating fault and the type of earth material present. The latter include bedrock, thick (200'+) alluvium; and thin (0-200') alluvium. The generalized characteristics of expected shaking to be applied to each use in each of the zones in the City are summarized in Table 10 of the text. The response spectra are included as Figures 33 through 56.

6. Liquefaction is a potential hazard in the area of shallow groundwater along San Jose Creek in the southern part of the study area.

7. Landslides are a potential hazard in the soft sedimentary rocks of the San Jose and Puente Hills and the relatively hard but steep slopes of the San Gabriel Mountains. Based on the distribution of natural landslides, steepness of slope, and the physical characteristics of mapped geologic units, the study area is divided into four zones of relative slope stability: very low to nil, low, moderate, and high.

8. Tsunamis are not a hazard in the study area, but seiching generated by tilting of the ground surface north of the Sierra Madre fault may be a hazard.

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APPENDIX A

GLOSSARY OF TERMS

Active Fault - One that has moved in recent geologic time and which is likely to move again in the relatively near future. Definitions for planning purposes extend on the order of 10,000 years or more back and 100 years or more forward.

Alluvial - Pertaining to or composed of alluvium, or deposited by a stream or running water. (AGI, 1972)

Alluvium - A general term for clay, silt, sand, gravel or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope. (AGI, 1972)

Amplification - Elaboration; augmentation; addition (Webster). As used herein, near-surface amplification is the augmentation of wave amplitude resulting from the change in physical properties in near-surface layers (see Introduction).

Amplitude - The extent of the swing of a vibrating body on each side of the mean position. (Webster)

Block Glide - A translational landslide in which the slide mass remains essentially intact, moving outward and downward as a unit, most often along a pre-existing plane of weakness such as bedding, foliation, joints, faults, etc. (AGI, 1972)

Cohesion - Shear strength in a sediment not related to interparticle friction. (AGI, 1972)

Colluvium - (a) A general term applied to any loose, heterogeneous, and incoherent mass of soil, material or rock fragments deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff. (b) Alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope. (AGI, 1972)

Compaction - Reduction in bulk volume or thickness of, or the pore space within, a body of fine-grained sediments in response to the increasing weight of overlying material that is continually being deposited, or to the pressure resulting from earth movements within the crust. It is expressed as a decrease in porosity brought about by a tighter packing of the sediment particles. (AGI, 1972)

Consolidated Material - Soil or rocks that have become firm as a result of compaction.

Critical Damping - Damping to the point at which the displaced mass just returns to its original position without oscillation. (AGI, 1972).

Damping - The resistance to vibration that causes a decay of motion with time or distance, e.g. the diminishing amplitude of an oscillation. (AGI, 1972)

Differential Settlement - Nonuniform settlement; the uneven lowering of different parts of an engineering structure, often resulting in damage to the structure. (AGI, 1972)

Displacement (Geological) - The relative movement of the two sides of a fault, measured in any chosen direction; also, the specific amount of such movement. Displacement in an apparently lateral direction includes strike-slip and strike separation; displacement in an apparently vertical direction includes dip-slip and dip separation. (AGI, 1972)

Displacement (Engineering) - The geometrical relation between the position of a moving object at any time and its original position. (Webster)

Epicenter - That point on the Earth's surface which is directly above the focus of an earthquake. (AGI, 1972)

Fault - A surface or zone of rock fracture along which there has been displacement, from a few centimeters to a few kilometers in scale. (AGI, 1972)

Fault Surface - In a fault, the surface along which displacement has occurred. (AGI, 1972)

Fault System - Two or more interconnecting fault sets. (AGI, 1972)

Fault Zone - A fault zone is expressed as a zone of numerous small fractures or by breccia or fault gouge. A fault zone may be as wide as hundreds of meters. (AGI, 1972)

Focus (Seism) - That point within the Earth which is the center of an earthquake and the origin of its elastic waves. Syn: hypocenter; seismic focus; centrum (see Introduction). (AGI, 1972)

Ground Response - A general term referring to the response of earth materials to the passage of earthquake vibration. It may be expressed in general terms (maximum acceleration, dominant period, etc.), or as a ground-motion spectrum.

Hypocenter - See focus.

Intensity (earthquake) - A measure of the effects of an earthquake at a particular place on human and/or structures. The intensity at a point depends not only upon the strength of the earthquake, or the earthquake magnitude, but also upon the distance from the point to the epicenter and the local geology at the point. (AGI, 1972)

Isoseismal line - A line connecting points on the Earth's surface at which earthquake intensity is the same. It is usually a closed curve around the epicenter. Syn: isoseism; isoseismic line; isoseismal. (AGI, 1972)

Liquefaction - A sudden large decrease in the shearing resistance of a cohesionless soil, caused by a collapse of the structure by shock or strain, and associated with a sudden but temporary increase of the pore fluid pressure. (AGI, 1972)

Macroseismic data - Used herein to describe instrumentally recorded earthquakes generally in the range of Richter magnitude 3.0 or more. (This use differs from the AGI definition of "macroseismic observations").

Magnitude (earthquake) - A measure of the strength of an earthquake or the strain energy released by it, as determined by seismographic observations. As defined by Richter, it is the logarithm, to the base 10, of the amplitude in microns of the largest trade deflection that would be observed on a standard torsion seismograph (static magnification = 2800; period = 018 sec; damping constant = 0.8) at a distance of 100 kilometers from the epicenter. (AGI, 1972)

Microseismic data - Used herein to describe instrumentally recorded earthquakes generally in the range of Richter magnitude 3.0 or less. (This use is consistent with the AGI definition of microseism and microseismometer, but is more restricted than their definition of microseismic data).

Natural period - The period at which maximum response of a system occurs. The inverse of resonant frequency.

Normal fault - A fault in which the hanging wall appears to have moved downward relative to the footwall. The angle of the fault is usually 45-90 degrees. This is dip-separation, but there may or may not be dip-slip. (AGI, 1972)

Predominant period - The period of the acceleration, velocity or displacement which predominates in a complex vibratory motion. In the analysis of earthquake vibrations, predominant period is normally the period of the maximum amplitude of the acceleration spectrum.

Response spectrum - An array of the response characteristics of a structure or structures ordered according to period or frequency. The structures are normally single-degree-of-freedom oscillators, and the characteristics may be displacement, velocity or acceleration (see Introduction).

Seiche - All standing waves on any body of water whose period is determined by resonant characteristics of the containing basin as controlled by its physical dimensions. (U.S. Geol. Survey Prof. Paper 544-E)

Seismic seiche - Standing waves set up on rivers, reservoirs, ponds and lakes at the time of passage of seismic waves from an earthquake. (U.S. Geol. Survey Prof. Paper 544-E)

Shear - A strain resulting from stresses that cause or tend to cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact; specifically, the ratio of the relative displacement of these parts to the distance between them. (AGI, 1972)

Shear wave or S-wave - That type of seismic body wave which is propagated by a shearing motion of material so that there is oscillation perpendicular to the direction of propagation. It does not travel through liquids. (AGI, 1972)

Slip - On a fault, the actual relative displacement along the fault plane of two formerly adjacent points on either side of the fault. Slip is three dimensional, whereas separation is two dimensional. (AGI, 1972)

Strike-slip fault - A fault, the actual movement of which is parallel to the strike (trend) of the fault. (AGI, 1972)

Subsidence - A local mass movement that involves principally the gradual downward settling or sinking of the solid Earth's surface with little or no horizontal motion and that does not occur along a free surface (not the result of a landslide or failure of a slope. (AGI, 1972)

Tectonic - Of or pertaining to the forces involved in, or the resulting structures or features of the upper part of the Earth's crust. (mod. from AGI, 1972)

Tsunami - A gravitational sea wave produced by any large-scale, short-duration disturbance of the ocean floor, principally by a shallow submarine earthquake, but also by submarine earth movement, subsidence, or volcanic eruption, characterized by great speed of propagation (up to 950 km/hr.), long wavelength (up to 200 dm.), long period (5 min. to a few hours, generally 10 - 60 min.), and low observable amplitude on the open sea, although it may pile up to great heights (30 m. or more) and cause considerable damage on entering shallow ater along an exposed coast, often thousands of kilometers from the source. (AGI, 1972)

Unconsolidated material - A sediment that is loosely arranged or unstratified or whose particles are not cemented together, occurring either at the surface or at depth. (AGI, 1972)

Water table - The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere. (AGI, 1972)

APPENDIX B

Documents Relevant to The
Alquist-Priolo Geologic Hazard Zones Act

1. Text of Act

2. Policies and Criteria of
   the State Mining & Geology
   Board

3. Explanation of Special Studies
   Compiled by the State Geologist

4. Zoning for Surface Fault Hazards
   in California: The New Special
   Studies Zones Maps

CHAPTER 1354

An act to amend Sections 660, 661, and 662 of, and to add Chapter 7.5 (commencing with Section 2621) to Division 2 of, the Public Resources Code, relating to earthquake protection, and making an appropriation therefor.

[Approved by Governor December 22, 1972. Filed with Secretary of State December 22, 1972]

LEGISLATIVE COUNSEL'S DIGEST

SB 520, Alquist. Earthquake protection.

Increases the membership of the State Mining and Geology Board from 9 to 11 persons and declares that persons with specified occupations should be selected for membership on the board. Designates the board as a policy and appeals board for the purposes of provisions re earthquake hazard zones.

Requires the State Geologist to delineate, by December 31, 1973, special studies zones encompassing certain areas of earthquake hazard. Requires State Geologist to compile maps delineating the special studies zones and to submit such maps to affected cities, counties, and state agencies for review and comment. Requires the State Geologist to continually review new geologic and seismic data and revise special studies zones and submit such revisions to affected cities, counties, and state agencies for review and comment. Appropriates $100,000 for such purposes. Requires affected cities, counties, and state agencies to submit their comments to board.

Requires cities and counties to exercise specified approval authority with respect to real estate developments or structures for human occupancy within such delineated zones. Requires applicants for a building permit within such zone to be charged a fee according to a fee schedule established by the board. Limits maximum amount of such fee. Provides for retention of ½ of the proceeds of any such fee by the city or county having jurisdiction and transfer of ½ to the state.

The people of the State of California do enact as follows:

SECTION 1. Section 660 of the Public Resources Code is amended to read:

660. There is in the department a State Mining and Geology Board, consisting of 11 members appointed by the Governor, subject to confirmation by the Senate, for terms of four years and until their successors are appointed and qualified. The State Mining and Geology Board shall also serve as a policy and appeals board for the purposes of Chapter 7.5 (commencing with Section 2621) of Division 2.

SEC. 2. Section 661 of the Public Resources Code is amended to read:

661. Members of the board shall be selected from citizens of this state associated with or having broad knowledge of the mineral industries of this state, of its geologic resources, or of related technical and scientific fields, to the end that the functions of the board as specified in Section 657 are conducted in the best interests of the state. Among the 11 members, two should be mining geologists, mining engineers, or mineral economists, one should be a structural engineer, one should be a geophysicist, one should be an urban or regional planner, one should be a soils engineer, two should be geologists, one should be a representative of county government, and at least two shall be members of the public having an interest in and knowledge of the environment.

SEC. 3. Section 662 of the Public Resources Code is amended to read:

662. The terms of the members of the board in office when this article takes effect in 1965 shall expire as follows: one member January 15, 1966; two members January 15, 1967; and two members January 15, 1968. The terms shall expire in the same relative order as to each member as the term for which he holds office before this article takes effect. The terms of the two additional members first appointed pursuant to the amendment of this section at the 1968 Regular Session of the Legislature shall commence on January 15, 1969. The terms of the two additional members first appointed pursuant to the amendment of Section 660 at the 1970 Regular Session of the Legislature shall commence on January 15, 1971, but the term of one of such additional members, who shall be designated by the Governor, shall expire on January 15, 1974. The terms of the two additional members first appointed pursuant to the amendment of Section 660 at the 1972 Regular Session of the Legislature shall commence on January 15, 1973, but the term of one of such additional members, who shall be designated by the Governor, shall expire on January 15, 1976.

SEC. 4. Chapter 7.5 (commencing with Section 2621) is added to Division 2 of the Public Resources Code, to read:

CHAPTER 7.5. HAZARD ZONES

2621. This chapter shall be known and may be cited as the Alquist-Priolo Geologic Hazard Zones Act.

2621.5. It is the purpose of this chapter to provide for the adoption and administration of zoning laws, ordinances, rules, and regulations by cities and counties, as well as to implement such general plan as may be in effect in any city or county. The Legislature declares that the provisions of this chapter are intended to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to provide for the public safety in hazardous fault zones.

2622. In order to assist cities and counties in their planning, zoning,

and building-regulation functions, the State Geologist shall delineate, by December 31, 1973, appropriately wide special studies zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults, and such other faults, or segments thereof, as he deems sufficiently active and well-defined as to constitute a potential hazard to structures from surface faulting or fault creep. Such special studies zones shall ordinarily be one-quarter mile or less in width, except in circumstances which may require the State Geologist to designate a wider zone.

Pursuant to this section, the State Geologist shall compile maps delineating the special studies zones and shall submit such maps to all affected cities, counties, and state agencies, not later than December 31, 1973, for review and comment. Concerned jurisdictions and agencies shall submit all such comments to the State Mining and Geology Board for review and consideration within 90 days. Within 90 days of such review, the State Geologist shall provide copies of the official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within any such zone.

The State Geologist shall continually review new geologic and seismic data and shall revise the special studies zones or delineate additional special studies zones when warranted by new information. The State Geologist shall submit all such revisions to all affected cities, counties, and state agencies for their review and comment. Concerned jurisdictions and agencies shall submit all such comments to the State Mining and Geology Board for review and consideration within 30 days. Within 30 days of such review, the State Geologist shall provide copies of the revised official maps to concerned state agencies and to each city or county having jurisdiction over lands lying within any such zone.

2623. Within the special studies zones delineated pursuant to Section 2622, the site of every proposed new real estate development or structure for human occupancy shall be approved by the city or county having jurisdiction over such lands in accordance with policies and criteria established by the State Mining and Geology Board and the findings of the State Geologist. Such policies and criteria shall be established by the State Mining and Geology Board not later than December 31, 1973. In the development of such policies and criteria, the State Mining and Geology Board shall seek the comment and advice of affected cities, counties, and state agencies. Cities and counties shall not approve the location of such a development or structure within a delineated special studies zone if an undue hazard would be created, and approval may be withheld pending geologic and engineering studies to more adequately define the zone of hazard. If the city or county finds that no undue hazard exists, geologic and engineering studies may be waived, with approval of the State Geologist, and the location of the proposed development or structure

may be approved.

2624. Nothing in this chapter is intended to prevent cities and counties from establishing policies and criteria which are stricter than those established by the State Mining and Geology Board, nor from imposing and collecting fees in addition to those required under this chapter.

2625. Each applicant for a building permit within a delineated special studies zone shall be charged a reasonable fee according to a fee schedule established by the State Mining and Geology Board. Such fees shall be set in an amount sufficient to meet, but not to exceed, the costs to state and local government of administering and complying with the provisions of this chapter. Such fee shall not exceed one-tenth of 1 percent of the total valuation of the proposed building construction for which the building permit is issued, as determined by the local building official. One-half of the proceeds of such fees shall be retained by the city or county having jurisdiction over the proposed development or structure for the purpose of implementing this chapter, and the remaining one-half of the proceeds shall be deposited in the General Fund.

SEC. 5. There is hereby appropriated from the General Fund in the State Treasury to the Department of Conservation the sum of one hundred thousand dollars ($100,000) for the purposes of Section 2622 of the Public Resources Code.

POLICIES AND CRITERIA OF THE STATE MINING AND GEOLOGY BOARD WITH REFERENCE TO THE ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT (CHAPTER 7.5, DIVISION 2, PUBLIC RESOURCES CODE, STATE OF CALIFORNIA)

(Adopted by State Mining and Geology Board November 21, 1973.)

The legislature has declared in the ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT that the State Geologist and the State Mining and Geology Board are charged under the Act with the responsibility of assisting the Cities, Counties and State agencies in the exercise of their responsibility to provide for the public safety in hazardous fault zones. As designated by the Act, the policies and criteria set forth hereinafter are limited to hazards resulting from surface faulting or fault creep. This limitation does not imply that other geologic hazards are not important and that such other hazards should not be considered in the total evaluation of land safety.

Implementation of the ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT by affected cities and counties fulfills only a portion of the requirement for these counties and cities to prepare seismic safety and safety elements of their general plans, pursuant to Section 65302 (F) and 65302.1 of the Government Code. The special study zones, together with these policies and criteria, should be incorporated into the local seismic safety and safety elements of the general plan.

The State Geologist has compiled and is in the process of compiling maps delineating special studies zones pursuant to Section 2622 of the Public Resources Code. The special studies zones designated on the maps are based on fault data of varied quality. It is expected that the maps will be revised as more complete geological information becomes available. Also, additional special studies zones may be delineated in the future. The Board has certain responsibilities regarding review and consideration of those maps prior to the time that they are finally determined. Cities, Counties and State agencies have certain opportunities under the Act to comment on the preliminary maps provided by the State Geologist and these Policies and Criteria. Certain procedures are suggested herein with regard to those responsibilities and comments.

Please note that the Act is not retroactive. Section 2623 of the Public Resources Code provides that it applies to every proposed <u>new</u> real estate development or structure for human occupancy.

REVIEW OF PRELIMINARY MAPS

The State Mining and Geology Board suggests that each reviewing governmental agency take the following steps in reviewing the preliminary maps submitted for their consideration:

1. All property owners within the preliminary special studies zones mapped by the State Geologist should be notified by the Cities and Counties of the inclusion of their lands within said preliminary special studies zones by publication or other means designed to inform said property owners. Such notification shall not of necessity require notification by service or by mail. This notification will permit affected property owners to present geologic evidence they might have relative to the preliminary maps.

2. Cities and Counties are encouraged to examine the preliminary maps delineating special studies zones and to make recommendations, accompanied by supporting data and discussions, to the State Mining and Geology Board for modification of said zones in accordance with the statute and within the time period specified therein.

3. For purposes of the Act, the State Mining and Geology Board regards faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence as constituting a potential hazard. Upon submission of satisfactory geologic evidence that a fault shown within a special studies zone has not had surface displacement within Holocene time, and thus is not deemed active, the Mining and Geology Board may recommend to the State Geologist that the boundaries of the special studies zone be appropriately modified.

The definition of active fault is intended to represent minimum criteria only for all structures. Cities and Counties may wish to impose more restrictive definitions requiring a longer time period of demonstrated absence of displacements for critical structures such as high-rise buildings, hospitals, and schools.

SPECIFIC CRITERIA

The following specific and detailed criteria shall apply within special studies zones and shall be included in any planning program, ordinance, rules and regulations adopted by Cities and Counties pursuant to said GEOLOGIC HAZARD ZONES ACT:

A. No structure for human occupancy shall be permitted to be placed across the trace of an active fault. Furthermore, the area within fifty (50) feet of an active fault shall be assumed to be underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation and submission of a report by a geologist registered in the State of California. This 50-foot standard is intended to represent minimum criteria only for all structures. It is the opinion of the Board that certain essential or critical structures, such as high-rise buildings, hospitals, and schools should be subject to more restrictive criteria at the discretion of cities and counties.

B. Applications for all real estate developments and structures

for human occupancy within special study zones shall be accompanied by a geologic report prepared by a geologist registered in the State of California, and directed to the problem of potential surface fault displacement through the site, unless such studies are waived pursuant to Section 2623.

C. One (1) copy of all such geologic reports shall be filed with the State Geologist by the public body having jurisdiction within thirty days of submission. The State Geologist shall place such reports on open file.

D. Requirements for geologic reports may be satisfied for a single 1 or 2 family residence if, in the judgment of technically qualified City and County personnel, sufficient information regarding the site is available from previous studies in the same area.

E. Technically qualified personnel within or retained by each City or County must evaluate the geologic and engineering reports required herein and advise the body having jurisdiction and authority.

F. Cities and Counties may establish policies and criteria which are more restrictive than those established herein. In particular, the Board believes that comprehensive geologic and engineering studies should be required for any "critical" or "essential" structure as previously defined whether or not it is located within a special studies zone.

G. In accordance with Section 2625 of the Public Resources Code each applicant for a building permit within a delineated special studies zone shall pay to the City or County administering and complying with the ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT a fee of one-tenth of one-percent of the total valuation of the proposed building construction for which the building permit is issued as determined by the local building official.

H. As used herein the following definitions apply:

1. A "structure for human occupancy" is one that is regularly, habitually or primarily occupied by humans.

2. A geologist registered in the State of California is deemed to be technically qualified to evaluate geologic reports.

3. Any engineer registered in the State of California in the appropriate specialty is deemed to be technically qualified to evaluate engineering reports in that specialty.

EXPLANATION OF SPECIAL STUDIES ZONES COMPILED BY THE STATE GEOLOGIST

EXPLANATION OF SPECIAL STUDIES ZONES MAPS

COMPILED BY THE STATE GEOLOGIST

Requirements

Maps showing special studies zones were compiled in compliance with Chapter 7.5, Division 2, of the California Public Resources Code. This Chapter, which may be cited as the Alquist-Priolo Geologic Hazards Zones Act, requires the State Geologist to 1) "delineate, by December 31, 1973, appropriately wide special studies zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults ... "and such other faults ..." that "... constitute a potential hazard to structures from surface faulting or fault creep"; and 2) compile maps of special studies zones and submit such maps to affected cities, counties, and state agencies by December 31, 1973, for their review and comment. Following appropriate reviews, the State Geologist must provide "official maps" to the affected cities, counties, and state agencies.

The State Geologist also is required to "continually review new geologic and seismic data" in order to revise the special studies zones or delineate additional zones.

This chapter requires cities and counties to exercise specified approval authority with respect to real estate development or structures for human occupancy within the special studies zones. Specific Policies and Criteria to assist local jurisdictions are provided by the State Mining and Geology Board. Other requirements and guidelines are provided in the Alquist-Priolo Act.

Special Studies Zones

Special studies zones are delineated on topographic base maps at a scale of 1:24,000 (1 inch equals 2000 feet). The zone boundaries are straight-line segments defined by turning points. Each turning point is identified by a number on the map for reference.

The intent of the Alquist-Priolo Act is to provide for public safety from the hazard of fault rupture by avoiding, to the extent possible, the construction of structures for human occupancy astride hazardous faults. The precise location and identification of hazardous faults within or near a zone of potentially active faults can be determined only through detailed geologic investigations. Thus, this Act establishes the concept of a Special Studies Zone -- an area of limited extent centered on recognized faults. Faults other than those depicted on the maps may be present within the Special Studies Zones. The zone boundaries delimit the area that the State Geologist believes warrants special geologic investigations to detect the presence or absence of hazardous faults.

Locations of special studies zone boundaries are controlled by the traces of potentially active faults (defined below), which are based on the best data available at the time the map was compiled. However, the faults shown on the Special Studies Zones maps were not field checked during the compilation of these maps. Because available fault data are highly varied in quality and the locations of some faults are known imprecisely, the zone boundaries have been positioned at a reasonable distance (about 660 feet or an eighth of a mile) from the trace of the nearest potentially active fault. However,

zone boundaries generally are more or less than 660 feet away from mapped faults because of 1) curved or multiple fault traces, 2) of the need to keep the number of turning points to a reasonable minimum, or 3) the quality of the data dictates a narrower or wider zone.

Definitions of Fault Terms

Fault, fault zone

A fault is defined as a fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. Most faults are the result of repeated displacement which may have taken place suddenly and/or by slow creep. A fault zone is a zone of related faults which commonly are braided and subparallel, but may be branching and divergent. It has significant width (with respect to the scale at which the fault is being considered, portrayed, or investigated), ranging from a few feet to several miles.

Fault trace

A fault trace is the line formed by the intersection of a fault and the earth's surface. It is the representation of a fault as depicted on a map, including maps of the Special Studies Zones.

Potentially active faults

For the purposes of delineating Special Studies Zones, any fault considered to have been active during Quaternary time (last 3,000,000 years)-- on the basis of evidence of surface displacement -- is con-

sidered by the State Geologist to be potentially active. An exception is a Quaternary fault which is determined, from direct evidence, to have become inactive before Holocene time (last 11,000 years). Such a fault is presumed to be essentially inactive and has been omitted from the map in most cases. Although faults shown on the maps may have been active during any part of, or throughout, Quaternary time, evidence for the recency of displacement is incompletely preserved and often is equivocal. In contrast, the State Mining and Geology Board, in their Policies and Criteria (adopted November 21, 1973), has defined any fault which has had surface displacement within Holocene time as "active and hence as constituting a potential hazard."

The surface ruptures associated with historic earthquake and creep events are identified where known. No degree of relative potential for future surface displacement or degree of hazard is implied for the faults shown.

The following geologic time scale is provided for reference and perspective:

GEOLOGIC TIME SCALE
(Abbreviated)

Geologic Age			Years before present (estimated)
Era	Period	Epoch	
CENOZOIC	QUATERNARY	"Historic"	200
		HOLOCENE	11,000
		PLEISTOCENE	2,000,000 – 3,000,000
	TERTIARY	PLIOCENE	7,000,000 – 10,000,000
		pre-PLIOCENE	65,000,000
pre-CENOZOIC time			
Beginning of geologic time			4,600,000,000

Faults defined as <u>active</u> by Policies & Criteria of the State Mining & Geology Board.

Faults defined as <u>potentially active</u> for the purpose of delineating special studies zones.

Uses and Limitations of Special Studies Zones Maps

Users of these maps should be fully aware that the zones are delineated to define those areas within which special studies may be required prior to building structures for human occupancy. Traces of potentially active faults are shown on the maps mainly to justify the locations of zone boundaries. These fault traces are plotted as accurately as the sources of data permit; yet the plots are not sufficiently accurate to be used as the bases for set-back requirements.

The State Geologist has identified potentially active faults in a broad sense, and the evidence for the potential activity of some faults may be only weak or indirect.

The fault information shown on the maps is not sufficient to meet the requirement for special studies. The onus is on the local governmental units to require the developer to evaluate specific sites within the special studies zones to determine if a potential hazard from any fault, whether heretofor recognized or not, exists with regard to proposed structures and their occupants.

ZONING FOR SURFACE FAULT HAZARDS IN CALIFORNIA: THE NEW SPECIAL STUDIES ZONES MAPS

by Earl W. Hart, Geologist, California Division of Mines and Geology

In compliance with the Alquist-Priolo Geologic Hazard Zones Act of 1972, official maps of Special Studies Zones, delineated by the State Geologist, were released 1 July 1974 to the cities and counties affected by the zones. The Special Studies Zones were drawn to encompass potentially hazardous traces of the San Andreas, Calaveras, Hayward, San Jacinto and other faults.

The Alquist-Priolo Act (also known as Chapter 7.5, Division 2 of the California Public Resources Code) provides cities and counties with a means of reducing personal and property damage from fault rupture. The Act applies to all "new real estate developments and structures for human occupancy" within the zones established. Contemplated structures are to be so located as to avoid "undue hazards" that may be created by "surface faulting and fault creep."

The State Geologist, the State Mining and Geology Board, and those cities, counties, and state agencies affected by the Special Studies Zones (table 1) are responsible for the implementation of the Act. The State Mining and Geology Board has the responsibility of providing "policies and criteria" to carry out the law (table 2). Affected cities and counties (table 3) also may impose more restrictive or additional rules and regulations to satisfy their local needs.

The effectiveness of the new legislation will depend on (1) local implementation of ordinances, and (2) geological evaluation of potential surface fault displacement. Given the general guidelines set forth by the State, each city and county affected by the new zones will have to adopt additional special guidelines, or at least make specific interpretations that will enable them to make decisions regarding proposed developments. According to the State Mining and Geology Board, an active fault is defined as one which has had displacement during Holocene time (last 11,000 years) and therefore constitutes a potential hazard. In evaluating a fault with respect to a given proposed development site, the geologist has considerable responsibility. In cases where the existence of a fault hazard is unclear, the local jurisdiction must decide on the basis of the geologic evaluation whether or not the proposed development is an acceptable risk.

Table 1.

Summary of official responsibilities and functions required under the Alquist-Priolo Geologic Hazard Zones Act.

State Geologist (Chief, California Division of Mines and Geology)

1. Delineates Special Studies Zones; compiles and issues maps.
   a. Preliminary Review maps.
   b. Official Maps.
2. Reviews new data.
   a. Revises existing maps.
   b. Compiles new maps.
3. Approves requests for waivers by cities and counties.

State Mining and Geology Board

1. Formulates policies and criteria to guide cities and counties.
2. Serves as Appeal Board for appeals that cannot be coped with locally.
3. Advises State Geologist.

Cities and counties

1. Responsible for local implementation of Act within the delineated Special Studies Zones.
2. Approves permits for development.
3. Collects fees for building and development permits to cover administrative costs.

State agencies

Implied responsibility for siting State structures safely within Special Studies Zones.

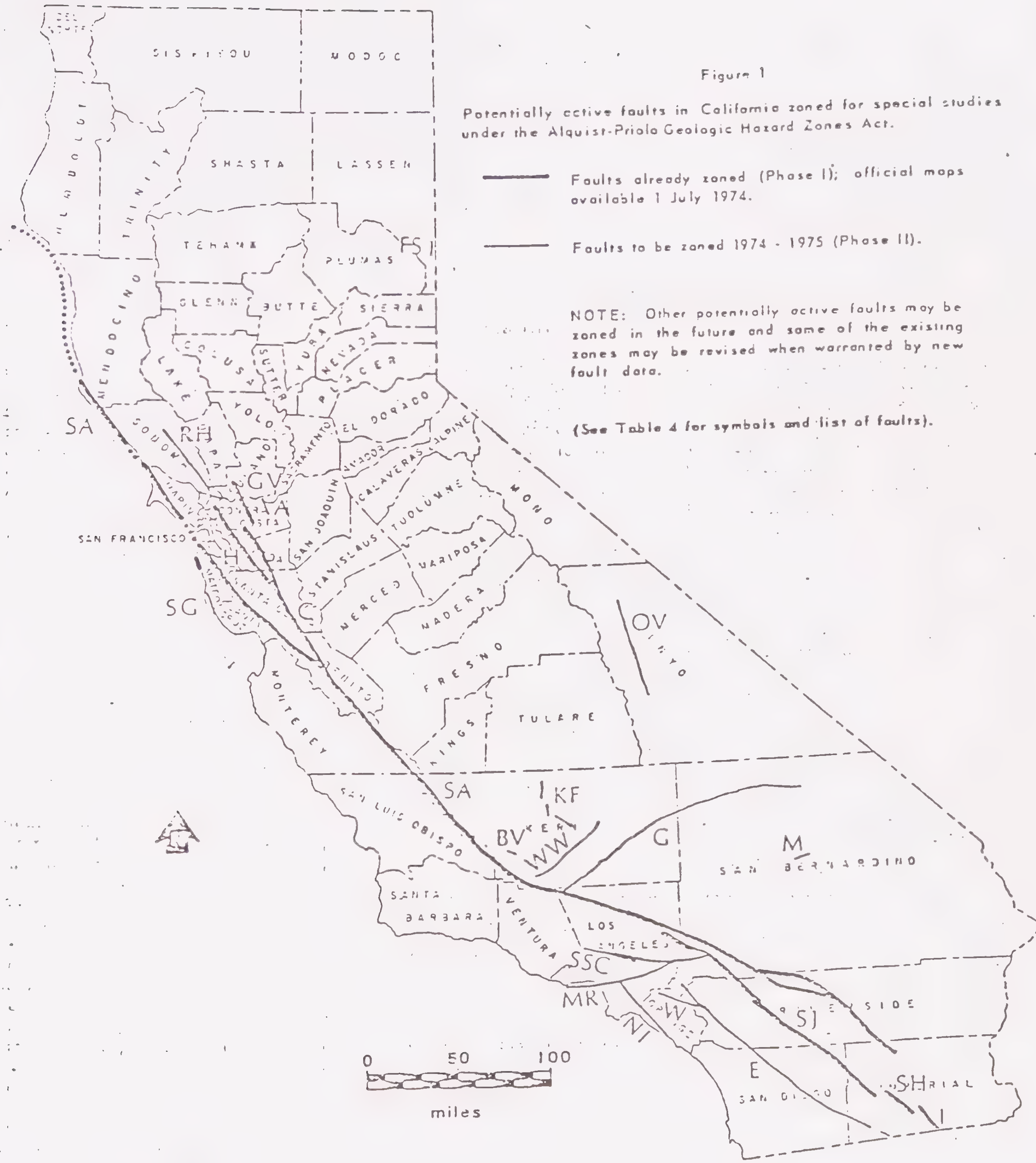

Figure 1

Potentially active faults in California zoned for special studies under the Alquist-Priolo Geologic Hazard Zones Act.

Faults already zoned (Phase I); official maps available 1 July 1974.

Faults to be zoned 1974 - 1975 (Phase II).

NOTE: Other potentially active faults may be zoned in the future and some of the existing zones may be revised when warranted by new fault data.

(See Table 4 for symbols and list of faults).

The CDMG program

Under the Alquist-Priolo Act, the State Geologist (who is also Chief of the State Division of Mines and Geology) is required to delineate the Special Studies Zones and to compile and distribute maps of these zones. A project team, headed by staff geologist Earl Hart, was established within the Division to develop a program for delineation of the zones.

It was determined that the faults named in the Act--the San Andreas, Calaveras, Hayward, San Jacinto--could be zoned by 31 December 1973 with the available funds and staff. The zones were delineated on U. S. Geological Survey topographic maps at a scale of 1 inch equals 2000 feet (1:24,000). This initial phase, whereby Preliminary Review maps were compiled in 1973 and subsequently reviewed and revised for issue as Official Maps on 1 July 1974, is known as Phase I (see map, figure 1; and table 4).

Phase II of the Division program, the delineation of Special Studies Zones for other potentially active faults (table 4), will be accomplished in Fiscal Year 1974-1975 and the Preliminary Review maps issued around mid-1975. Following the prescribed review and revision periods of 90 days each, Official Maps will be issued at the end of 1975. At that time, any newly established or revised zoning will become effective and the affected cities and counties will be required to implement the Act within the zoned areas.

Table 2.

Summary of policies and criteria adopted by the State Mining and Geology Board, effective 1 July 1974

Policies

1. Specifies that the Act is not retroactive.
2. Suggests methods relating to review of Preliminary Maps prior to issuance of Official Maps.
3. Policies and criteria apply only to area within the Special Studies Zones.
4. Defines *active fault* (equals potential hazard) as a fault that has had surface displacement during Holocene time (last 11,000 years).

Specific criteria

1. No structures for human occupancy are permitted on the trace of an active fault. (Unless proven otherwise, the area within 50 feet of an active fault is presumed to be underlain by an active fault).
2. Requires geologic report directed at the problem of potential surface faulting for all real estate developments and structures for human occupancy.
3. Requires that geologic reports be placed on open file by the State Geologist.
4. Requires cities and counties to review adequacy of geologic reports submitted with requests for development permits.
5. Permits cities and counties to establish standards more restrictive than the policies and criteria.
6. Sets fees for building permits at 0.1 percent of estimated assessed valuation of proposed structure.
7. Defines a) structure for human occupancy, b) technically qualified geologist, and c) new real estate development.

Although there are many other potentially active faults in California that could be zoned, the faults listed under Phase II in table 4 include (1) all of the known historically active faults not zoned under Phase I, and (2) major potentially active faults, especially those situated in areas of

Table 3.

Cities and counties affected by Special Studies Zones

Incorporated cities

Banning	El Cerrito	Martinez	Pleasanton	San Juan Bautista
Benicia	Fairfield	Millbrae	Portola Valley	San Leandro
Berkeley	Fremont	Milpitas	Redlands	San Pablo
Burlingame	Hayward	Morgan Hill	Redwood City	South San Francisco
Coachella	Hemet	Oakland	Rialto	Union City
Colton	Hercules	Pacifica	Richmond	Walnut Creek
Concord	Hollister	Palmdale	San Bernardino	Woodside
Daly City	Indio	Palo Alto	San Bruno	
Desert Hot Springs	Loma Linda	Pinole	San Jose	

Counties

Alameda	Kern	Monterey	San Diego	Santa Cruz
Contra Costa	Los Angeles	Riverside	San Luis Obispo	Solano
Humboldt	Marin	San Benito	San Mateo	Sonoma
Imperial	Mendocino	San Bernardino	Santa Clara	Ventura

current development. The zoning of faults in Phase II will be done on a priority basis according to the manpower and funds available, and existing data.

In the meantime, the State Geologist will continue to review new information and revise existing Special Studies Zones as necessary. It is planned that copies of all geologic reports submitted to the cities and counties for the purpose of obtaining permits for development will be kept on open file at the Division's San Francisco office in Room 1016, Ferry Building.

Table 4.

Faults to be zoned for special studies (on priority basis), under Alquist-Priolo Act; CDMG program through 1975. See figure 1 for location of faults

Fault	*Map symbol*
Phase I (zoning complete):	
Calaveras	C
(includes Green Valley and Concord)	GV
Hayward	H
San Andreas	SA
San Jacinto	SJ
(includes: Imperial	I
Superstition Hills)	SH
Phase II (1974-1975):	
Antioch	A
Buena Vista	BV
Elsinore-Chino	E
Fort Sage	FS
Garlock	G
Kern Front	KF
Manix	M
Malibu Coast-Raymond	MR
Newport-Inglewood	NI
Owens Valley	OV
Rogers Creek-Healdsburg	RH
San Gregorio	SG
Sierra Madre-Santa Susana-Cucamonga (includes "San Fernando")	SSC
Whittier	W
White Wolf	WW

Available information

For those readers interested in obtaining more detailed information on the Alquist-Priolo Act and the Division's program, the following references are available:

1. *Index to maps of Special Studies Zones* (containing supplementary text of the Alquist-Priolo Act, Policies and Criteria of the State Mining and Geology Board, and a list of cities and counties affected by the Special Studies Zones). California Division of Mines and Geology Special Publication 42. Price: $1.00, plus tax.

2. *Maps of Special Studies Zones* (see Index map). Full scale maps (1 inch equals 2000 feet) may be consulted at offices of the cities and counties affected by the zones (table 3) or at any district office of the California Division of Mines and Geology. Individual copies may be obtained from many local jurisdictions or they may be purchased commercially from Blue Print Service Company, 149 Second Street, San Francisco 94105 (attention: Ellen Schermerhorn; phone: 415-495-8700).

3. Explanation of Special Studies Zones Maps. Free.

4. *Guidelines to geologic and seismic reports.* CDMG Note 37. Free.

5. *Model ordinance for cities and counties to implement the Alquist-Priolo Act.* This is an informal set of regulations for guidance purposes only. Price: $0.25.

Items 1, 3, 4, and 5 can be obtained at CDMG district offices or by mail from California Division of Mines and Geology, P. O. Box 2980, Sacramento, California 95812. ☆

MINERAL AND ENERGY CONFERENCE

The Pacific Southwest Mineral and Energy Conference will be held 11, 12, and 13 November 1974 at the Hilton Hotel, Los Angeles, California. The American Institute of Mining, Metallurgical and Petroleum Engineers, and the Western Oil and Gas Association, join the U.S. Bureau of Land Management and the California Mine Operators Association in sponsoring the event.

The program will be geared principally to energy minerals, covering geology, mining, environmental considerations and management. Speakers are nationally recognized authorities in their field from top management in industry and government. This biennial conference will provide government and industry with a meeting ground for the exchange of ideas and information regarding mineral production and management.

For further information contact: G. W. Nielsen, U.S. Bureau of Land Management, 2800 Cottage Way, Room E-2841, Sacramento, California 95825. ☆

PUBLIC SAFETY: Technical Section

CONTENTS

List of Illustrations

I. INTRODUCTION

Government Code Section 65302.1 requires a safety element of all city and county general plans as follows:

> "A safety element for the protection of the community from fires and geologic hazards including features necessary for such protection as evacuation routes, peak load, water supply requirements, minimum road widths, clearances around structures and geological hazard."

The Guidelines (California Council on Intergovernmental Relations, 1973) for the preparation of local general plans states that:

> "The objective of this element is to introduce safety considerations in the planning process in order to reduce loss of life, injuries, damage to property, and economic dislocations resulting from fire and dangerous geologic occurrences."

Based on the interpretation of the legal context of these guidelines, the Public Safety Element is defined to include the following:

A. General policy statement that:

(1) Recognizes safety hazards
(2) Identifies goals for reducing hazards
(3) Specifies the level of acceptable risk
(4) Specifies objectives to be attained in reducing safety hazards as related to existing and new structures
(5) Sets priorities for the abatement of safety hazards, recognizing the variable frequency and occurrence of hazardous events.

B. A map showing the location and extent of known geologic (and fire) hazards.

C. Standards and general criteria for land use and circulation relating to:

(1) Fire prevention and control
(2) Geologic hazards

II. FIRE HAZARDS ANALYSIS

A. INTRODUCTION

The major emphasis in this investigation is the analysis and evaluation of fire hazards originating in both the developed and undeveloped areas in the Cities of Azusa, Covina, West Covina, and Industry. These cities, located in the San Gabriel Valley, contain a variety of land uses ranging from industrial concerns to low density single family developments. They also contain fairly extensive tracts of open space that extend into the San Gabriel Mountains and the Puente and San Jose Hills. This varied landscape involves the role of fire as both a natural process and a hazard.

Fires in undeveloped areas result from the ignition of accumulated brush and woody material, and are appropriately termed "wildland fires." Such fires can burn large areas and cause much damage to both structures and valuable watershed. The fire hazards delineated on the "Fire and Inundation Hazards Map" (Plate II) are concerned with this type of fire.

Urban fires usually originate from sources within the structures themselves. Smoking in bed, appliance malfunctions, faulty wiring, children playing with matches, and the improper use of flammable liquids are often causes for structural fire. Fire hazards of this type are related to specific sites and structures, and do not lend themselves to an area-based fire hazard zoning. For that reason, the discussion of structural fire hazards will be limited to the text, while that of "wildland fires" will also include an evaluation of the areal distribution of the hazard level.

B. WILDLAND FIRE HAZARDS

1. Hazards Setting

The study area can be classified into three basic physiographic units: the San Gabriel Mountains, the eastern San Gabriel Valley, and the Puente-San Jose Hills. The major fire threats originate in the steeper areas of the San Gabriel Mountains on the north and the vegetated slopes in the Puente Hills on the south. The San Gabriel Valley, located between these two hilly areas, is not completely free from fire hazard. Wind-borne embers may travel long distances and ignite rooftops and grassy lots within urban areas.

The type of vegetation somewhat varies in the hilly parts of the study area, but sizeable differences do occur in the density of that vegetation. These differences along with the diverse slope conditions create several distinguishable levels of fire hazard.

Urban development in some localities has extended into the canyons of the study area and has reduced the fire hazard by removing the vegetation. However, it has also introduced the human element into more outlying locations, thus increasing the hazard. In some cases, these divergent relationships have reduced the possibility of wildland fire, but in most, they have enhanced the hazard of fire.

2. Historical Record

Fire records maintained by the Los Angeles County Fire Department between the years 1919 and 1973 indicate that large portions of the study area have been subject to wildland fires of 100 acres or larger. Figure 1 shows these locations, but more importantly, it demonstrates that some areas have experienced fire on a recurring basis. Such areas have a propensity for fire, and must be considered very hazardous from the standpoint of the "wildland fire" hazard.

3. Factors Affecting Fire Hazard

Several factors affect the hazard potential one can expect from a wildland fire in any given area. These factors include human proximity, vegetation, wind direction, slope, and access to the area. They are discussed in detail in the following sections.

a. Human Proximity

The most significant factor determining overall fire risk is human proximity. The human element is often contributory in the ignition of major brush fires, as evidenced by the abundance and frequency of burns in the vicinity of residential neighborhoods. The most frequent contributor to this factor of fire hazard appears to be the unsupervised activities of children playing with matches or lighters. Cinders from wood-burning fireplaces that remain alive and travel considerable distances have also been blamed for fire-starts near residential locations, but fully 90% of the local fires in the study area have resulted from human activities near the interface of wildland areas and urban locations.

Human proximity also tends to introduce the activity of off-road vehicles such as motorcycles and minibikes in nearby open areas. This is becoming an ever-increasing source of brush fires in the urban-wildland interface.

Accidents related to industrial activities such as spark discharges from transmission lines and flammable leakages from pipelines in, and adjacent to, brush-covered areas, serve to increase the potential for fire.

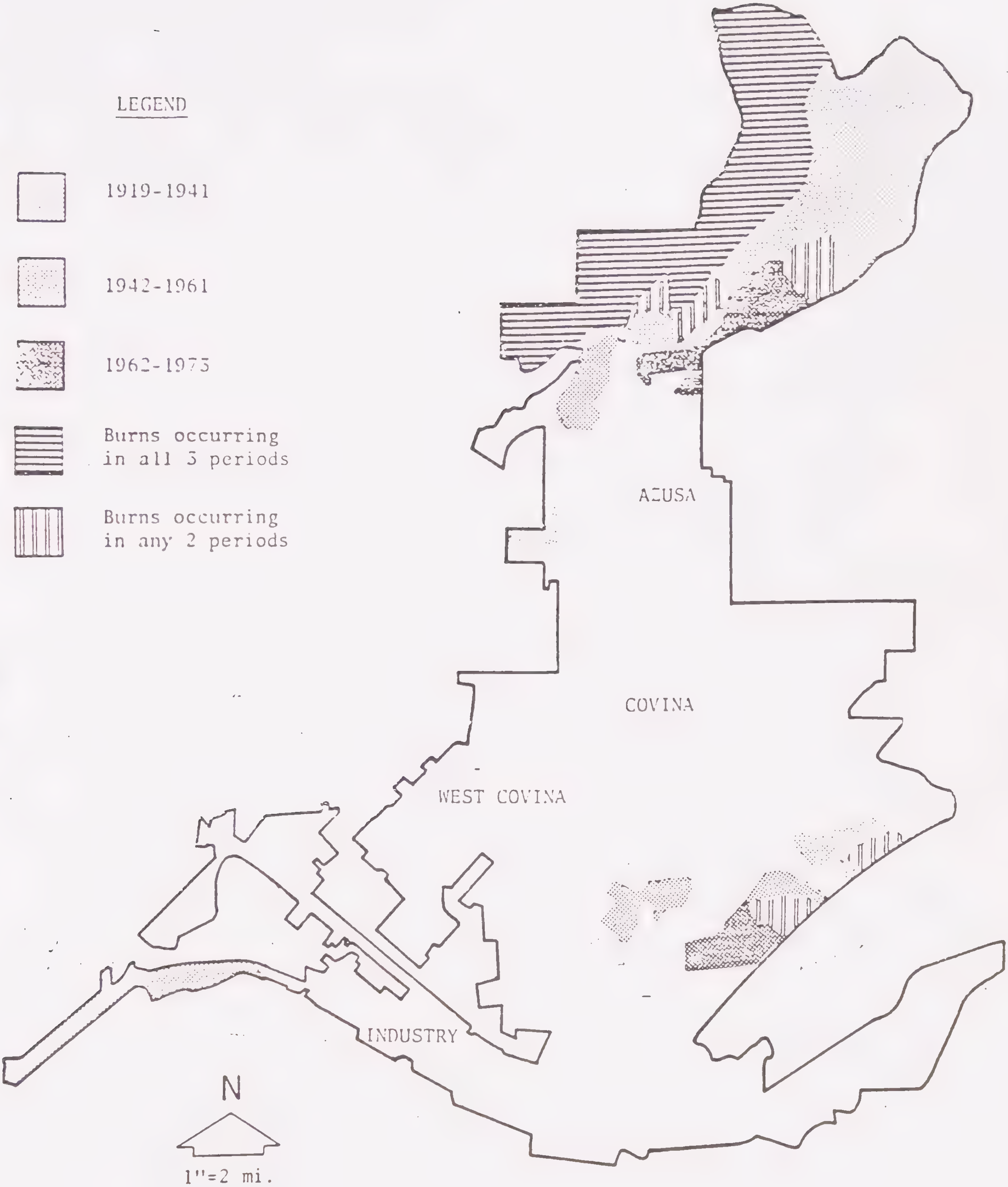

Figure 1.
HISTORIC FIRE BURN AREAS
1919-1973

Source: Los Angeles County Fire Department

b. Vegetation

The density and distribution of vegetation can define both the overall hazard of fire in a particular area and the intensity of fire which ensues. The vegetation of an area determines the fuel and spreading potential and can decide the recurrence intervals one can anticipate between outbreaks of fire. In the Azusa, Covina, West Covina, and Industry area, four major plant communities determine the various fuel potentials of the area.

Chamise chaparral is the most hazardous plant community encountered in the area. Chamise contains a large percentage of volatile oils within its tissues that can ignite with a great deal of vigor. Fires in overgrown chamise areas are characteristically very hot and burn with a great deal of intensity.

Chamise is a root-sprouter and this capability allows the community to re-establish itself such that in the span of four to five years, few signs of the original burn can be seen. Another facet of the Chamise Chaparral plant community which contributes to its fire potential is the relatively dense, impenetrable nature of its stands; where fire can easily spread. Stands of chamise are usually quite pure and often this species will comprise upwards of 80-90% of the total number of plant species present in a given area. This stable fuel supply is conducive to widespread burning.

Coastal chaparral plant communities are characterized by dense tangles of hard-leaved, evergreen, and often spiny shrubs. This community is characteristically more mixed in terms of species makeup and often, these various species will form mosaics within the community.

In terms of flammability, the hazard potential of coastal chaparral is second only to chamise. Certain species in coastal chaparral are able to renew themselves through root-sprouting and others depend upon fire for seedling germination. As in chamise chaparral, the tissues of many of these species contain volatile oils capable of fueling very hot wildland fires.

Only two factors relegate coastal chaparral to a secondary position behind chamise chaparral as fire prone plant community. The first of these is the more diverse nature of the coast chaparral community. More types of plants are usually encountered in a coast chaparral, and this diversity makes the fuel potential of the vegetation less uniform; thereby slightly lowering its fire potential. However, the more significant factor is the somewhat larger amount of moisture that is retained in the leaves and woody tissues of coast chaparral plants. This serves to retard fire somewhat more than in chamise areas.

Coastal sage scrub plant communities are the most abundant plant forms encountered in the area, and differ from coastal chaparral in that the shrubs are smaller (1-5 feet high), not as woody and stiff, and more widely spaced. This density factor along with the slightly lower overall height and mass of the community make it a lesser fire hazard than the two previously discussed plant communities. However, coast sage communities should not be disregarded as a substantial fire hazard, for they too can burn with a great deal of vigor and renew themselves in as short a time as three years after a burn.

The woodland-grass vegetation community ranks as the fourth-most flammable plant type found in the study area. Composed of sycamores, liveoaks, canyon oaks and associated grasses and shrubs, this community is found along the moister slopes and drainages of the study area. Trees obviously contain a great deal of fuel potential, but seldom do they ignite in a brush fire situation. This factor along with their limited distribution in the study area, lowers their overall hazard potential.

c. Wind Direction

Wind direction and velocity rivals vegetation and human proximity as being the most significant factor affecting fire hazard. Although the study area has a predominate westerly breeze flow, the bulk of the fire outbreaks accompany the warm, dry easterly wind conditions commonly referred to as the Santa Ana Winds. Therefore, those areas that lie to the west of potential ignition points or fire sources become even more hazardous. Winds that intensify fire hazards add a time dimension to the analysis because they contribute to wildland fire hazard only during certain seasons of the year.

d. Slope

Slope is the fourth major factor as it affects both the accessibility of fire and draft, which, in turn, affects the intensity of burning. This is especially important in canyon areas where the slope and topography can cause significant drafts that increase the vigor of combustion. Slope is also a factor affecting accessibility as discussed in the next section.

e. Access

Access is the factor that describes the relative difficulty of delivering both equipment and personnel to a fire. Containment being a key objective, those areas of limited accessibility have a correspondingly greater potential for fire-spreading than those more accessible locations.

In the study area, the factor controlling access is slope. The amount of slope in a fire burn area can determine the type

of heavy equipment that can be used. The Los Angeles County Fire Department has developed the following basic slope classifications as they relate to accessibility.

extreme	=	40+%
high	=	20-40%
medium	=	10-20%
low	=	0-10%

4. Fire Risk Ratings

The fire risk zones shown on The Fire and Flooding Hazards Map, represent a compilation of data regarding the primary factors of human proximity, vegetation, wind direction, slope and access. These factors are ranked in importance in roughly the same order as presented. However, fire risk analysis treats each factor as a mutually exclusive variable. Human proximity might be "more important" than slope on a general level, but conditions exist where the degrees of slope could become the predominant factor in the risk determination process. Therefore, each factor can vary in relative importance depending upon the specific conditions and characteristics of the area. The following profiles exemplify the types of conditions expected in each zone:

Extreme Risk

Vegetation:	Chamise-coastal chaparral
Proximity:	fronting developed areas and/or west of potential ignition sources
Access:	very limited
Slope:	40%+

High Risk

Vegetation:	Coastal chaparral-Coastal Sage-Woodland
Proximity:	near developed areas
Access:	limited
Slope:	20-40%

Medium Risk

Vegetation:	lesser developed scrub
Proximity:	lying within the urbanized portions of the study area
Access:	available
Slope:	0-20%

Low Risk

Vegetation:	vacant lots and landscaping
Proximity:	urban areas
Access:	available
Slope:	negligible

The fire risk zones portrayed on Plate II represent an approximate delineation of the categories being considered. They are not meant to be precise or specific alignments, but rather approximations that delineate fire propensities.

Urban site conditions are too detailed to be considered or shown at the scale of the maps used in this study. Therefore, certain areas within the "low hazard" zone may be highly hazardous. Conversely, local site conditions in areas within "high hazard" zones may preclude the possibility of fire, thus reducing the need for more stringent fire controls. In both cases, consideration must be given to both on-site and adjacent conditions.

C. URBAN FIRE HAZARDS

1. Hazards Setting

Fire has long been recognized as an especially dangerous threat in urban areas. As population concentrations increase in built-up areas, the factors necessary for fire ignition increase, as do the chances of a fire spreading rapidly once it starts. The factors of population, material, and energy concentrations in cities mean that loss of life, injury, and property damage from fire are greater in urban areas as well.

The Cities in the study area are located on the eastern edge of the largest urban complex on the west coast. The area does have a propensity for major fires, especially during its long, hot summers. On the other hand, the low density of the built-up areas, the quality of fire control agencies, and high standards of fire prevention tend to minimize the potential number and degree of damage of these fires.

2. Fire Hazardous Buildings

These buildings are ones having open stairwells, substandard electrical wiring, or faulty heating systems. A common example of a fire hazardous building is the older, multi-storied hotel converted to permanent residential use, usually for the poor or elderly. These older buildings are also used by some commercial or industrial enterprises. Upon ignition, fire spreads rapidly through such buildings.

a. Residential Buildings

Single-family detached houses form a major portion of the housing stock in the study area. Fires occur in private homes from a variety of causes, human carelessness chief among them. More lives are lost in residential fires than in any other type of fire. One particularly dangerous hazard in residential fires is the use of untreated wood shingles in roof construction. Windy conditions could spread the fire to a large number of other houses where this type of roof is common.

b. Multi-Story Buildings

Buildings over 5 stories pose difficult fire control problems. The large number of occupants and their dependence on internal support systems such as water pressure systems, ventilation systems, and elevator systems increase the potential for disaster. Adequate response to high-rise fires require improved internal extinguishing systems and special equipment such as helicopters and aerial ladders.

c. Hospitals and Medical Facilities

These facilities present critical fire control problems. Damage to sophisticated medical equipment by fire threatens the lives of present and future patients. Those mentally or physically debilitated cannot react during crisis in a way that would ensure minimum safety standards. In times of emergency, ailments are aggravated by stress, and the medical staff is usually inadequate to provide enough aid and guidance.

d. Indoor Public Assembly Facilities

Public assembly facilities are defined as those in which large numbers of people congregate in generally unfamiliar surroundings. They include schools, theaters, churches, temples, and a variety of recreational facilities. Gatherings of large number of people in these buildings create conditions conducive to mass panic in a crisis, which only worsen and increase the casualties. Administering medical aid is made more difficult in these situations, as well.

e. Industrial Fire Hazards

Potentially hazardous industrial operations encountered in the study area include utility lines such as gas lines and overhead electrical power lines. While the normal construction of utility lines provides a good degree of safety, gas lines do break and power lines do come down causing fires.

Another aspect of industrial fire hazards involves the transportation of industry-related, flammable materials on the major highways and freeways of the area. Regulatory powers that govern the transportation of these materials are the responsibility of State and Federal agencies, however, local fire and police departments are called upon to safeguard public safety when hazardous situations develop.

3. Hazards Reduction

Fire hazards can be minimized in two basic ways. The first method involves the reduction of fire starts. Preventative fire control, as it is termed, emphasizes safety in the design, maintenance, and use of structures. Proper safety measures can effectively prevent the possibility of fire.

The second method of hazards reduction emphasizes the effective response aspect of fire control. Effective response can be assisted by providing necessary access and adequate amounts and pressures of water. The County of Los Angeles Fire Department has established uniform standards for fire protection that relate these aspects of fire control to various types of land uses.

III. FLOOD HAZARDS ANALYSIS

A. INTRODUCTION

Flood hazards in the cities of Azusa, Covina, West Covina and Industry can be divided into three types: 1) natural floods that may accompany intense storms in the area; 2) mud and debris flows; and 3) floods that may occur in the unlikely event that a dam located either in or upstream of the study area should fail. In a strict sense, mud and debris flows are not flooding; but, since they result in part from heavy rains and often accompany floods, they are included here as a part of flood hazards analysis.

B. NATURAL FLOODING

Southern California is periodically subjected to intense rainfall which can cause severe flooding if adequate control is not provided. This problem has been mitigated by the construction and maintenance of stream channel improvements along the major drainages in the region. Azusa, for example, is protected by levees built by the Corps of Engineers that confine the San Gabriel River. They are rock and granite faced and average about 13 feet in height.

Flood containment along major creeks and rivers that pose a threat to urbanized areas normally involves preparing for the Standard Project Flood. This flood is defined by the Corps of Engineers as follows:

> "Standard Project Flood. The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40-60 percent of the Probable Maximum Floods for the same basins. As used by the Corps of Engineers, Standard Project Floods are intended as practical expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous."

Major flooding as a result of levee breaks during a Standard Project Flood is not a major problem in the area, but could occur locally. The levee extending westward from Highway 39 is vulnerable to strong flows of flood water because it is the first unnatural confinement of the river. Should the levee break here, a large part of Azusa would be inundated, including an area east of Santa Fe Dam. However, a levee break at this location would probably reduce the flood force on the Van Tassel

levee farther downstream, thereby reducing the hazard to that part of Azusa and Duarte.

The effect of any large flood on the northern part of the study area depends on the available capacity of San Gabriel Reservoir at the beginning of a major storm. Since it has a storage capacity of 44,000 acre feet, the retention of some of the flood flow in this reservoir and any available capacity in Morris Reservoir, could greatly reduce the flood flow into the study area.

The flood hazard that is the most common in the study area is standing water resulting from temporary blockage or inadequate capacity of storm sewers. Flood Hazard Boundary Maps prepared by the Federal Insurance Administration of the U.S. Department of Housing and Urban Development delineate the areas in which this type of flooding is expected to occur during a flood likely to occur once every 100 years (Intermediate Regional Flood). These maps are available for the local cities at scales of 1" = 1000 feet and 1" = 200 feet. Several locations within the study area are prone to inundation by standing water, and flood hazard insurance is required for certain types of financing of construction.

C. MUD AND DEBRIS FLOWS

Mud and debris flows are potentially serious hazards to life and property in the hilly portions of the study area. They involve very rapid downslope movement of saturated soil, sub-soil, and weathered bedrock. They originate in hillside areas where the soil horizon is well developed but the soil has poor drainage characteristics. Large mudflows may have the energy to uproot trees and to carry along boulders several feet in diameter.

Because of the speed with which they move, mudflows can be quite destructive, especially along the bottom and at the mouths of canyons.

Mud and debris flows are more likely to occur after a fire. The removal of vegetation by fire lowers the stability of exposed soils and lessens the water-holding capability of the local watershed. During a heavy rain, mud and debris become unstable and can be transported downslope, creating a potential hazard to safety.

Mud and debris flows effectively link aspects of geologic hazard, flooding potential, and fire hazard into a fourth safety consideration. However, the basis of mudflow hazards is related more closely to geological conditions. For that reason, the discussion of mud and debris flows is amplified in the Landslides Section of the Seismic Safety Technical Report.

D. DAM HAZARDS FROM FAILURE

Section 8589.5 of the Government Code, which became law in 1973, requires all dam owners to submit to the State Office of Emergency Services (OES), maps showing areas that would be inundated given an instantaneous collapse of their respective dams. Large dams are categorized with nuclear reactors, power intertie systems, and plants manufacturing explosives as structures whose continued functioning is critical, or whose failure might be catastrophic. Although this type of catastrophe is highly unlikely, the nature of the hazard is such that it should be considered.

The collapse of a dam, an event of unforseen severity, would create an inundation several magnitudes greater in area than a flood caused by heavy rains. Records from the 1928 failure of the St. Francis Dam (capacity 32,000 acre-feet) describe a flood flow of 500,000 cubic feet per second, and a "wall" of water over 100 feet high in the confining canyon (Report of Commission 1928). It should be stressed, however, that none of the dams affecting the Azusa, Covina, West Covina, Industry area would fail, based upon current evidence.

Pertinent characteristics of the large dams and reservoirs in the study area are summarized as follows:

Dam	Owner	Type	Capacity [1]	Year Built	Height	Drainage Area Sq. Mile
Santa Fe	C. of E.	Earth	33,000	1949	92	231
Morris [2]	MWD	Conc. Grav.	35,000	1935	143	210
Puddingstone [2]	LACFCD	Earth	17,000	1928	147	19
San Gabriel [2]	LACFCD	Earth-Rock	53,300	1938	320	203

1 acre-feet
2 mapped

The Flood Inundation portion of Plate II identifies the areas which would be effected by the dams, labeled as being mapped, in the preceeding table. Assumptions involved in preparing the maps, as well as the nature and extent of each mapped or unmapped inundation area, are given in the following paragraphs.

In the event of a failure of the San Gabriel Dam and/or Morris Dam, large parts of the cities of Azusa, Duarte, and Irwindale would be inundated. The entire flood would last less than one hour. The velocity and height of water would rapidly diminish at the mouth of San Gabriel Canyon and spread out laterally. The central part of the flood wave moves faster than the periphery and would do considerably more damage.

Note: It is assumed that if Cogswell Dam (capacity 10,400 acre-feet) should fail, its volume would be contained in San Gabriel Reservoir.

If Puddingstone Dam should fail, a small part of Covina and a large part of West Covina would be inundated. The flood path would spread out from Walnut Creek channel and eventually inundate parts of the cities of La Puente, Baldwin Park, Industry, and possibly El Monte and South El Monte.

A failure of Beatty Canyon Debris Dam (inundation map not available) would inundate a small part of Azusa. This is based on the condition of full reservoir capacity (only 11 acre-feet) at the time of the failure--a condition that probably occurs less than one month per year.

If Santa Fe Dam should fail (Inundation map not available), parts of the cities of Irwindale, Baldwin Park, Arcada, El Monte, South El Monte, West Covina, La Puente, and Industry would be inundated. This event is highly unlikely because water is not stored in Santa Fe Reservoir, but is rapidly released into downstream spreading grounds and channels to prepare for the next storm inflow. Thus it is extremely unlikely that a dam-destroying event, which itself is very unlikely, would occur at a time when there was a sufficient volume of water in the reservoir to inundate the downstream area.

IV. CONCLUSIONS

A. WILDLAND FIRE HAZARD

1. The most fire-prone areas in the study area are located in the San Gabriel Mountains. The abundance of available fuel, and steep topography are primarily responsible for this high level of risk.

2. High and medium fire risk areas occur in the chamise-covered slopes in the Puente Hills.

3. Man-related activities rank as the chief cause of fire in the study area.

4. Significant portions of the urban areas bounded within the study area would be exposed to medium fire risks from embers carried aloft and later deposited by Santa Ana Winds.

B. URBAN FIRE HAZARD

1. The most significant fire-related hazard confronting the study area is urban fire.

2. The most frequently encountered type of urban fire is fire in residential buildings.

3. Human carelessness ranks as the chief cause of urban fire in the study area.

C. NATURAL FLOODING HAZARDS

1. The most commonly encountered flood problem in the study area is inundation by standing water because of inadequate storm drain capacity.

2. Major flooding as a result of the failure of a levee is not expected to be a significant problem.

3. Large portions of the four-city study area would be affected in the event of a failure of any of the major dams located in or upstream of the study area during periods of peak loading.

4. Mud and debris flows can occur in the hilly portions of the study area. The potential for mud and debris flow increases following wildland fire damage.

GENERAL REFERENCES

Dam Inundation Maps, 1974. Prepared in compliance with Government Code 8589.5. Cities of Azusa, Covina, West Covina, and Industry.

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Envicom Corporation, 1975. Safety Element, Cities of El Segundo, Redondo Beach, Manhattan Beach. (Not adopted)

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Los Angeles County Fire Department, 1973. Uniform Standards for Fire Protection Planning in Residential Developments.

APPENDIX A
GLOSSARY OF TERMS

Access	-	The ease by which men and equipment can be delivered to a fire situation. In structural fires, access is subdivided into <u>common vehicular access</u> (the emergency use of public and private streets and driveways) and <u>restricted vehicular access</u> (the use of exclusive lanes for fire fighting purposes).
Aspect	-	The direction in which a particular slope faces.
California Chaparral	-	A fire prone plant community characterized by vegetation dominated by shrubs or trees with broad, leathery, evergreen leaves.
Chamise Chaparral	-	A chaparral plant community dominated by the abundance of chamise. It is the most fire prone plant community in Southern California.
Coast Sage	-	Commonly encountered plant community characterized by half-shrubs, forming a more-open plant community than chaparral.
Dam Inundation	-	Downstream flooding that would occur given a structural failure of a dam.
Fire Flow	-	Refers to delivery rates of water that should be maintained to adequately halt and reverse the spread of fire.
Fuel Potential	-	The amount of combustible plant material that could act as fuel for a fire.
Human Proximity	-	A measurement of the amount of contact between humans and flammable plant communities.
Mudflow	-	Rapid, downslope movements of saturated soil, sub-soil and weathered bedrock. Common in hilly locations after a fire.
Slope	-	Factor in fire analysis that identified the contribution of topography such as canyons and hillsides to local fire hazard.
Urban Fire	-	Fires in urban areas that originate primarily in, or around, structures.